

**CHOICE SET AS AN INDICATOR FOR CHOICE BEHAVIOR
WHEN LANES ARE MANAGED WITH VALUE PRICING**

A Dissertation

by

KIMBERLEY ALLYN MASTAKO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2003

Major Subject: Civil Engineering

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December 2003

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ABSTRACT

Choice Set as an Indicator for Choice Behavior

When Lanes Are Managed with Value Pricing. (December 2003)

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Due to recent pricing studies that have revealed substantial variability in values of time among decision makers with the same socioeconomic characteristics, there is substantial interest in modeling the observed heterogeneity. This study addresses this problem by revealing a previously overlooked connection between choice set and choice behavior.

This study estimates a discrete choice model for mode plus route plus time choice, subdivides the population according to empirically formed choice sets, and finds systematic variations among four choice set groups in user preferences for price managed lanes. Rather than assume the same values of the coefficients for all users, the model is separately estimated for each choice set group, and the null hypothesis of no taste variations among them is rejected, suggesting that choice set is an indicator for choice behavior.

In the State Route 91 study corridor, the price-managed lanes compete with at least two other congestion-avoiding alternatives. The principal hypothesis is that a person's willingness to pay depends on whether or not he perceives as personally feasible the option to bypass some congestion in a traditional carpool lane or by traveling outside the peak period. The procedure for estimating the choice sets empirically is predicated on the notion that individuals operate within a wide array of unobservable constraints that can establish the infeasibility of either alternative. The universal choice set includes

eight combinations of mode and time and route, wherein there are exactly two alternatives for each. Choice sets are formed from an assumed minimum set, which is expanded to one of three others whenever a non-zero choice probability for either ridesharing, or shoulder period travel, or both is revealed in a person's history of choice behavior.

Based on the test of taste variations, this author finds different values of time across the four choice set groups in the study sample. If these relationships can be validated in other locations, this would make a strong case for modeling choice behavior in value pricing as a function of choice set.

DEDICATION

To my loving husband and our amazing children. Each day I spend with you in Christ is worth a million Ph.D.s.

ACKNOWLEDGEMENTS

Many individuals and organizations helped and supported me in this endeavor. All of the members of my committee were generous with their time, encouragement, and advice. In terms of completing my degree requirements, I created a challenging situation for everyone when I returned to San Luis Obispo in 1997. Through it all, Dr. Rilett continued to let me know that he believed I could and would complete this work. I also owe a special thank you to Dr. Hickman who continued to serve and teach me long after he took on a new set of responsibilities at the University of Arizona. I am indebted to a number of advisors and colleagues who served as outside readers. Dr. Ed Sullivan, Dr. Jim Daly, and Dr. Ken Small were very kind to donate their time and share their expertise and advice. Dr. Sullivan has been an amazing resource throughout my entire college career, and a long time friend and mentor. I hope that one day I can be a positive influence in the lives of my students to the same degree that Dr. Sullivan has been in mine.

I am thankful for generous financial support from the California State University Office of the Chancellor and the Federal Highway Administration Eisenhower Fellowship Program. For numerous opportunities to work with and learn from industry leaders I would like to acknowledge Texas Transportation Institute, California Department of Transportation, California Polytechnic State University at San Luis Obispo, Eno Transportation Foundation, Southwestern Region University Transportation Center, and the Transportation Research Board. I would also like to thank Tania Falero, Robert

Weiss, Grant Schultz, Rhonda Brinkman, Lois Peters, Rev. Dale Paulsen, Mr. & Mrs.

Dennis Wormley, my sister, and my parents. I could never say enough about all the great help I received from my husband, Matthew Wormley.

NOMENCLATURE

Choice – The process or act of selecting an alternative from a set of alternatives.

Alternative – A potential selection for the choice decision. An element of the choice set. In this study, the choice is multidimensional. Each alternative in the choice set is a combination of three choice dimensions - mode, time, and route.

Mode Choice Dimension – The aspect of choice pertaining to the means or method of travel. *In this dissertation, the methods are solo and rideshare.*

Time Choice Dimension – The aspect of choice pertaining to time of day. *In this study, the time periods are peak and shoulder.*

Route Choice Dimension – The aspect of choice pertaining to the path. *In this dissertation, the paths are free and tollway.*

Universal Choice Set – For the study population, the set of all potential alternatives. *In this dissertation, there are eight possible combinations of mode, time, and route.*

Peak Period – The middle of the study period, when volumes and tolls are high relative to the shoulder period. *In this dissertation, the study period is weekdays 4:00 – 10:00 a.m. and 2:00 – 8:00 p.m.*

Shoulder Period – The portion of the study period before or after the peak, when volumes and tolls are low relative to the peak period. *In this dissertation, this is 4:00 – 5:00 a.m., 9:00 – 10:00 a.m., 2:00 – 3:00 p.m., and 7:00 – 8:00 p.m.*

Endure – The alternative that is solo mode, peak period, and free route.

Pay – The alternative that is solo mode, peak period, and tollway route.

Carpool – The alternative that is rideshare mode, peak period time, and free route.

Shift – The alternative that is solo mode, shoulder period, and free route.

Carpool & Pay – The alternative that is rideshare mode, peak period, and tollway route.

Shift & Pay – The alternative that is solo mode, shoulder period, and tollway route.

Carpool & Shift & Pay – The alternative that is rideshare mode, shoulder time, and tollway route.

Considered Choice Set – For a given individual, the set of alternatives considered as feasible.

Avoider – A traveler with a considered choice set equal to the universal choice set. A traveler who considers each mode and time alternative as feasible. Considered choice set = {Endure, Pay, Carpool, Shift, Carpool & Pay, Shift & Pay, Carpool & Shift & Pay}.

Carpooler – A traveler with a considered choice set equal to the universal choice set minus alternatives involving shoulder-period travel. A traveler who considers shoulder-period travel as infeasible. Considered choice set = {Endure, Pay, Carpool, Carpool & Pay}.

Shifter – A traveler whose considered choice set is the universal choice set minus alternatives involving rideshare travel. A traveler who considers ridesharing as infeasible. Considered choice set = {Endure, Pay, Shift, Shift & Pay}.

Endurer – A traveler whose considered choice set is the universal choice set minus alternatives involving shoulder period travel minus alternatives involving ridesharing. A traveler who considers both shoulder period travel and ridesharing as infeasible. Considered choice set = {Endure, Pay}.

SOV – A single-occupancy vehicle. A vehicle with one occupant.

HOV – A high-occupancy vehicle. A vehicle with more than one occupant.

HOV2 – A high-occupancy vehicle; one with two occupants.

HOV2+ – A high-occupancy vehicle; one two or more occupants.

HOV3+ – A high-occupancy vehicle; one with three or more occupants.

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1 INTRODUCTION

Value pricing¹ is a market-based approach for managing traffic volumes that consists of charging higher fees for road use during peak periods. The number of states and foreign countries involved in value pricing has increased in the past decade, and it appears that there are many more examples on the horizon. One form of value pricing that has been implemented in the United States gives commuters the option of shifting from a congested lane into a managed lane where free-flowing traffic is maintained by charging tolls that are set to control the number of vehicles. It is hypothesized that in these settings, a person's willingness to participate may depend in part on his perceptions regarding other congestion-avoiding alternatives, which often include sharing a ride or traveling outside the peak period. For example, an individual who perceives the option of avoiding congestion by traveling during peak shoulder periods to be feasible may be less willing than others to pay a toll to bypass congestion. For the travel behavior modeler, this condition has implications for jointly modeling mode and time of day along with route, and also for specifying the subset of alternatives the traveler actually considers for choice.

Specifying the set of alternatives that a given decision maker actually evaluates for choice is an important first step in developing any discrete choice model. The current study assumes a multidimensional choice set whose elements are defined as combinations of mode and time and route, wherein there are exactly two alternatives for each of these three choice dimensions. The mode alternatives are solo and rideshare, the time alternatives are peak and shoulder, and the route alternatives are free and tollway. This defines the universal choice set, which includes eight possible alternatives available to the population of decision makers. Rather than assume everyone chooses from the

This dissertation follows the style and format of the *Transportation Research Record*.

¹ Value pricing is also known as congestion pricing, peak-period pricing, differential pricing, and variable pricing.

full array of available alternatives, this study aims to establish the feasibility or infeasibility of certain alternatives and segment the population accordingly.

Simon (1) defines the considered set as the subset of available alternatives perceived as feasible and actually evaluated in an individual's choice decision. It is generally agreed that considered choice sets can vary among individuals for a variety of reasons including psychological or attitudinal constraints. In mode choice, for example, a lifestyle or attitude that demands personal privacy can translate into a zero probability for sharing a ride to work. This study aims to capture the effects of unobservable constraints such as this and include in the choice set the option of ridesharing only if the probability of sharing a ride is greater than zero; likewise for shoulder period travel. The purpose is to discover whether individuals with different choice sets have different preferences for value pricing. One possible explanation would be that the size of the choice set influences the conditional choice behavior of choice given the choice set. Another possibility is that the unobserved constraints that act on choice set formation also influence choice behavior.

The following four-part premise represents the primary motivation for this study:

1. A given decision maker either does or does not consider ridesharing to be personally feasible,
2. A given decision maker either does or not consider shoulder-period travel to be personally feasible,
3. The choice set implied by number 1 and 2 above can be estimated empirically, and
4. People with different choice sets behave differently when making choices for value pricing.

As a result of number 1 and 2 above, four pre defined choice sets are established and each commuter is assumed to choose from one of the four sets. In this study, a sample of travelers from the State Route 91 (SR-91) value-priced corridor in Orange County, California, who participated in a telephone survey taken in fall 1999, is used to demonstrate number 3 above and investigate number 4. For each sampled user, the choice set is estimated based on past travel behavior. The employed method of empirical choice set formation is similar to that found in O'Neil and Nelson (2) and is based on the premise that it is better to eliminate relevant options from the choice set than to include those that are irrelevant. See Lerman (3) for the effects on the model estimation of failing to screen out infeasible alternatives versus screening out feasible alternatives.

Next, the sample is divided into four segments according to the choice set estimation and the hypothesis of systematic variations in the model parameters among the segments is tested. The primary area of interest is the value of time and the notion that persons who consider a wider array of feasible alternatives may be less willing to pay a toll to bypass congestion than persons who consider fewer alternatives. The test of taste variations is conducted in the context of a joint model for mode, time, and route choice, the dimensional scope of which is found nowhere else in the literature.² The model is estimated on the full sample, assuming everyone considers all available alternatives, and again with each traveler constrained to their assumed choice set. Finally, a separate model is estimated for each segment, and important differences between the four segment-specific models are revealed.

This study looks beyond traditional socioeconomic attributes to investigate between-person differences in the responses to value pricing. The analysis points to differences

² Whereas a few researchers have estimated models of mode plus route choice and a few have estimated models of time plus route choice, there is not one example of a model of mode plus time plus route choice in the literature (see Section 5 for a detailed review of the literature on empirical models for value pricing).

in choice behavior among the four segments, and shows that the usual approach of assuming the same values of the unknown parameters for all decision makers obscures important differences in tastes for value pricing among the choice set groups. The following specific conclusions are supported by this study:

1. For the subset of users who actually consider the universal choice set, the usual approach of assuming this choice set for all decision makers has the problem of mis-specifying the ordinal relationship between alternative-specific constants. In relation to the bias against shoulder-period travel, the result is to overestimate the bias against ridesharing and also overestimate the bias against ridesharing in combination with shoulder-period travel.
2. Participation in value pricing is conditional on choice set. The null hypothesis of no taste variations among choice set groups is rejected at the 10% level. The rejection of this hypothesis is largely attributed to differences among groups in the marginal rate of substitution between money and travel time, which is estimated to be approximately \$5.00, \$10.00, \$12.00, or \$15.00 per hour, depending on choice set.
3. There is no clear relationship between the size of the choice set and the mean value of time. The first and second highest mean time value estimates are for the segments with the maximum and minimum choice set, respectively. Thus, it appears that unobserved constraints that act on choice set formation may also act on the choice behavior.

Based on these results, it is recommended that future studies to predict the effects of value pricing be structured to account for user-specific choice sets, and that further research be conducted on choice set formation. Until now, the problems of choice set formation in value pricing and choice behavior for value pricing given choice set had not been addressed. By demonstrating a connection between individual choice behavior in value pricing and the condition of whether the individual considers ridesharing and

shoulder period travel to be personally feasible, this study makes an important contribution. The results are intuitively pleasing in that they reflect the plausible notion that a person's willingness to exchange money for travel time savings may depend in part on his consideration of available 'toll free' ways to minimize travel time. In connection with the principal conclusions listed above (see Section 14), this research makes a number of supporting contributions. These include

1. A new system for characterizing the choice problem and classifying users based on choice set (see Section 9),
2. A simple and relatively inexpensive method for empirically estimating choice sets (see Section 9),
3. A proposal for a discrete choice model for estimating choice sets (see Section 15) ,
4. For each user type, a description of user characteristics and choice behaviors (see Section 11 and 12), and
5. The first mode-route-time choice model for value pricing (see Section 13).

In support of these, this manuscript includes background information on value pricing (Section 2), travel behavior (Section 3), travel behavior modeling (Section 4), and empirical models for value pricing (Section 5). The empirical data used to estimate the models are introduced in Section 6 (network travel times and tolls) and Section 7 (survey data). In Section 8, the survey data are analyzed and descriptive statistics on traveler characteristics and choice behavior are presented. Sections 9 and 10 give the method and procedures for estimating the choice sets. In Section 11, the choice sets are estimated and the sample is divided into four segments. In Section 12, the four segments are compared in terms of choice given choice. A multidimensional logit model is estimated on the full sample in Section 13 under the usual assumption that all decision makers choose from the universal choice set. In Section 14, the assumption of user-

specific choice sets is incorporated into the modeling and the segments are analyzed for taste variations. Principal findings and recommendations for future work are summarized in Section 15.

2 PRICING

The first applications of value pricing in the United States were deployed in the mid-1990s with funding from the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Prior to this historical act, the notion of road user fees that vary with demand was unpopular with policy makers, mostly because they perceived overwhelming political and technical obstacles (4). Despite convincing economic arguments regarding more productive use of existing transportation capacity (5,6), local governments failed to give value pricing serious consideration, partly because the burden of manual fee collection appeared prohibitive and partly because they thought users would be unhappy with the fees. However, with new technologies for automated toll collection, value pricing began to make its way into the transportation policy toolbox. By the time many of the technical challenges had been answered, the forces in favor of value pricing were so great that policy makers were compelled to start testing even though many of the political challenges had not yet been resolved.

The forces in favor of value pricing include the following:

- Traffic congestion, which is seen by many to affect economic growth and quality of life, continues to worsen;
- In many locations, there is not enough space, funding, and public approval to ease congestion with new construction; and
- Various non pricing options that have been tried have not done enough to increase the person carrying ability of the existing infrastructure or slow the rate of growth in travel.

These and other trends regarding traffic congestion are well documented in a long-running study by the Texas Transportation Institute (TTI). In their most recent annual Urban Mobility Study, TTI studied 75 urban areas of various sizes and found that the number of hours and miles of road that are congested have grown every year despite

investments in new traffic surveillance and control technologies, incentives for carpooling or using transit, and new infrastructure (7). According to TTI, the average annual delay per peak road traveler increased from 16 hours in 1982 to 62 hours in 2000, and the total congestion “bill” (for the 75 areas) in 2000 amounted to \$67.5 billion in wasted time and fuel.

In answer to the question “What should be done?” the TTI report says,

[By themselves] additional roadways do not seem to be the answer. The solution is really a diverse set of options that require funding commitments, as well as a variety of changes in the ways that transportation systems are used.

This statement represents current best practices for congestion relief, which include combinations of land use policies to manage demand patterns, new infrastructure, improved system operations for roads and transit, and, in some cases, value pricing or peak travel restrictions.

In terms of value pricing, the current emphasis is on learning about the effects on total travel, mobility, and accessibility (8)¹ as well as the consequences for different types of highway users, non users, and businesses. Prior to the first round of project evaluations in the late 1990s, researchers relied on experience with changes in bridge and turnpike tolls, transit fares, and parking fees to identify the range of possible behavioral adaptations, and also studied the experiences of foreign cities with value pricing. Much of the research available from these exploratory activities is documented in *Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion* (9) and *Road Pricing for Congestion Management: A Survey of International Practice* (10), both of which were

¹ Levine and Garb (8) distinguish between mobility and accessibility by defining mobility as the ease of movement and accessibility as the ease of reaching destinations. “When destinations are close by, great accessibility can be had even if mobility is constrained.”

published by the Transportation Research Board in 1994. Nearly 10 years later, only a handful of states and foreign countries have direct experience with value pricing.

Value Pricing in the United States

In the United States, experience with value pricing is found in two basic forms: (1) managed lanes, where free-flowing traffic is maintained even during peak times by charging tolls set to control the number of vehicles using the lanes, and (2) existing toll facilities (e.g., bridges, tunnels, turnpikes), where differential pricing encourages drivers to avoid peak periods and pay electronically. In Singapore, a more comprehensive form of value pricing discourages motorists from entering the city center during peak periods by charging a fee at all entry locations, and has been operational since 1975. Examples of value pricing in the United States are given in Table 2.1.

Table 2.1 Six Examples of Value Pricing in the United States

Managed Lanes	Differential Pricing on Existing Toll Facilities
Orange County, California (SR-91) Tolling on new lanes	Lee County, Florida 2 bridges
Houston, Texas (I-10 and US-290) HOV-2 tolling on existing HOV-3 facility	New Jersey Turnpike
San Diego, California (I-15) SOV tolling on existing HOV-2 facility	Port Authority of New York and New Jersey 4 bridges & 2 tunnels

Orange County

The Orange County project was the first to use value pricing for managed lanes. Here, a private company financed the construction of two new lanes in each direction of the

heavily congested SR-91 commute corridor and collected toll revenue to recover the costs.² The time-of-day toll structure has been adjusted upward at least once per year since the facility opened in December 1995 in order to maintain congestion-free conditions at all times. All tolls are collected electronically, mostly because there is not enough space for conventional toll booths. Vehicles not equipped for electronic payment are prohibited from using the facility. In July 2003, tolls ranged from \$1.00 to \$4.75 for the approximately 10-mile drive, HOV-3s travel free except in the eastbound direction between 4:00 and 6:00 p.m.,³ and 91 Express Club customers save money when they make more than 20 one-way trips per month.⁴

Houston

On the I-10 (Katy) and US-290 (Northwest) freeways in Houston, value pricing is being used to control the number of two-person carpools (HOV-2s) in managed carpool lanes. Except during the peak hours, HOV-2s can enter the lanes free of charge. Three-plus person carpools (HOV-3+s) travel free at all times. During the peak hours⁵, HOV-2s are permitted access only if they are equipped for electronic toll payment and pay the toll. This type of managed lane is commonly referred to as a high-occupancy toll (HOT) lane. When the project began on the Katy Freeway in 1998, the \$2.00 per trip toll was specifically chosen to achieve the desired HOV-2 demand (11). Even though both Houston HOT facilities continue to be under utilized during the peak periods, the toll has not been adjusted.

² In January 2003, ownership was transferred to a public agency.

³ Eastbound between 4:00 and 6:00 p.m., HOV-3+ users receive a 50% discount on the posted toll. Between January 1998 and May 2003, the 50% discount policy for HOV-3+ applied to all time periods and both directions.

⁴ The 91 Express Club is an optional program that gives benefits to frequent users. 91 Express Club customers pay a \$20 per transponder monthly membership fee and receive a \$1.00 discount on all tolled trips.

⁵ Peak hours are 6:45 – 8:00 a.m. and 5:00 – 6:00 p.m. on the Katy Freeway and 6:45 – 8:00 a.m. on the Northwest Freeway.

San Diego

San Diego began operating a grade-separated HOT facility on I-15 in 1996 and changed over to variable pricing in 1998. In this value-pricing scheme, a paying solo driver equipped with a transponder can access a previously under utilized HOV-2+ carpool facility. In San Diego, the price of the toll varies based on observed traffic levels in order to maintain level of service C or better (12).⁶ Under normal conditions, the toll for the 8-mile trip ranges between \$0.50 and \$4.00, although the price can go much higher if an unexpected event like an accident causes demand to spike. On this facility all high-occupancy vehicles travel free at all times.

For three managed-lane facilities, Table 2.2 compares the toll for the three morning time periods 6:15, 7:45, and 9:15 a.m. As shown, the toll difference between 6:15 a.m. and 7:45 a.m. is much smaller for the Orange County facility than for the other two. On all of these routes, the shape of the cost versus time-of-day toll schedule is implied as being reflective of the shape of the volume versus time-of-day traffic distribution in the unmanaged general-purpose lanes. This suggests a longer-duration peak period in Orange County compared to Houston and San Diego. With fewer time-of-day options for avoiding peak-period congestion, it is hypothesized that Orange County travelers would be more likely than San Diego and Houston travelers to choose the paid lanes.

⁶ LOS C as defined in the Highway Capacity Manual, 2000 (12).

Table 2.2 Time-of-Day Toll Schedules for Several Managed Lane Facilities

	6:15 a.m.	7:45 a.m.	9:15 a.m.
Houston, HOV-2s	Free	\$2.00	Free
San Diego, Solo Drivers (13) ⁷	\$0.50	\$3.50	\$0.60
Orange County, Solo Drivers & HOV-2s ⁸	\$3.30	\$3.60	\$2.65

Table 2.3 similarly compares full-cash and discounted tolls for three differential pricing projects. Unlike the managed lane projects, differential pricing on these facilities is not designed to provide congestion-free travel. To the extent that lower off-peak tolls entice some people to switch to off-peak travel, peak conditions should improve when differential pricing is implemented, unless or until the total number of users increases. Compared to an electronic payment at 7:45 a.m., the savings afforded by traveling 90 minutes earlier at 6:15 a.m. varies from zero to \$0.25 (a 50% savings), to \$0.65 (a 12% savings).

⁷ Average actual toll for October and November 1998 as reported in Brownstone et al. (13).

⁸ The tolls shown here have been in effect since November 2001. Current toll schedule information is available from <http://www.91expresslanes.com>, accessed June 19, 2003.

Table 2.3 Toll vs. Time-of-Day Schedules for Differential Pricing Facilities

Enter Monday at:	All Times	6:15 a.m.	7:45 a.m.	9:15 a.m.
Payment Method:	Cash	Electronic		
NY NJ Port Authority ⁹	\$6.00	\$5.00	\$5.00	\$4.00
New Jersey Turnpike ¹⁰ Travel Full Length	\$6.45	\$4.85	\$5.45	\$4.85
Midpoint and Cape Coral Bridges, Lee County, Florida ¹¹	\$0.50	\$0.25	\$0.50	\$0.25

Even though value pricing is currently operational in only a few locations, its potential for managing traffic has been demonstrated without major objections from the traveling public. The principal findings from independent evaluations of early value pricing projects are documented in the *2000 Value Pricing Pilot Project Report to Congress* (14). Encouraged by fairly positive reviews, the Federal Highway Administration (FHWA) is in favor of moving forward into new locations¹² and testing new applications. Among the innovative concepts being discussed is a recent proposal by the Reason Public Policy Institute for regional networks of lanes managed by value pricing (15).

⁹ The tolls shown here for the Port Authority of New York and New Jersey have been in effect since March 2001. Current toll schedule information is available from <http://www.panynj.gov>, accessed July 28, 2003.

¹⁰ The tolls shown here for the New Jersey Turnpike have been in effect since September 2000. Current toll schedule information is available from <http://www.state.nj.us/turnpike/>, accessed July 28, 2003.

¹¹ The tolls shown here for Lee County bridges have been in effect since August 1998. Current toll schedule information is available from www.leewayinfo.com, accessed July 28, 2003.

¹² According to FHWA (14), plans or studies are under way in Atlanta, Dallas, Denver, Houston, Los Angeles, Miami, Phoenix, San Diego, San Francisco Bay Area, Seattle, and Washington D.C.

With interest in value pricing on the rise, transportation professionals face many new challenges in terms of deciding if and where to toll, specifying the level and variability of tolls, and setting policies regarding different user groups. In preparing to address these challenges, decision makers are striving to understand behavioral responses to various forms of value pricing. The range of potential responses and the issues associated with modeling these are discussed next in Sections 3 and 4. This dissertation is specifically concerned with short-term responses of mode, route, and time-of-day choice and the hypothesis that response varies with the considered choice set. Potential medium- and long-term effects are examined briefly in the next section.

3 TRAVEL BEHAVIOR

This section identifies various forms of travel behavior response to pricing and presents a general framework for representing the thought processes that produce observed behavior. The theories and properties of discrete choice models are detailed later in Section 4. Together, Sections 3 and 4 provide the theoretical background for using empirical data from a value pricing project to estimate a joint mode-time-route choice model conditional on choice set.

Judgments about the desirability of pricing and the development of specific pricing policies require information about likely impacts on the amount, location, and timing of travel, both in total and among specific facilities and population subgroups (16). These impacts depend on the human behavior response to pricing, land use, and the supply of transportation. Travel demand analysis is the area of transportation science that analyzes these relationships. The information presented in this section is from a review of the literature in this field.

It is widely agreed that the important behavioral assumptions of demand analysis are related to the process of choice. It is usually postulated that the urban traveler faces a series of choices regarding lifestyle, activity patterns, and related travel. In each choice, the traveler selects from among available alternatives. Understanding the choice process and accurate modeling of this process is essential for travel demand analysis. The three major questions concerning the structure of the choice process are:

1. What choices are involved?
2. Are the choices dependent or independent?
3. If the choices are dependent, are the choices made simultaneously or in some sequential order?

Even with detailed questioning of individual trip makers, it is difficult to verify assumptions regarding the exact nature of the choice process. It is generally assumed that there are long-term and short-term decisions and that the nature of the activity (i.e., the purpose of the trip) influences the structure of the choice process (17). Table 3.1 identifies 10 different choices associated with home to work trip-making behavior in a value-priced corridor. Some of these choices can be viewed as medium-term decisions because they are typically unchanged day by day, unlike shorter-term choices, yet unlike longer-term decisions do not involve a significant lifestyle change.

Table 3.1 Ten Travel Choices

Choice	Term
Departure time	Short
Mode	Short
Route	Short
Location of intermediate stop(s)	Short
Trip chaining	Short
Trip frequency (work trips/week)	Medium
Transponder ownership	Medium
Auto ownership	Long
Employment location	Long
Residential location	Long

Because value pricing is not a single treatment,¹ the particular manner in which value pricing is implemented will ultimately determine how these choices are affected. For this reason analysts should exercise caution when applying lessons learned from one value-pricing project to another. The current study uses data collected from the SR-91 value-priced corridor, a full description of which can be found in Section 6 of this manuscript. The corridor includes the SR-91 Express Lanes, which are referred to herein as the SR-91 tollway. The SR-91 tollway was introduced as an add-lanes project; one that complements an extensive network of HOV (high-occupancy vehicle) lanes in Orange County, has variable time-of-day pricing, 100% automatic toll collection, and gives discounts on tolls to frequent users who pay a membership fee to HOV-3+ users. For some origin-destination (O-D) pairs, the SR-91 tollway competes with the Eastern Transportation Corridor, referred to herein as the Eastern tollway. The Eastern tollway is a fixed-price facility that does not require a transponder for toll collection and does not guarantee congestion-free travel. In the SR-91 corridor, value pricing has the potential to affect behavior in the ways described below.

Departure time. Travelers² with flexible schedules may travel more frequently during the middle of the peak period knowing that they can pay to bypass some of the worst congestion. On the other hand, paying travelers may travel more frequently in shoulder periods in order to pay a lesser toll.

Mode of travel. Carpoolers may rideshare less frequently because they find it more convenient to pay and bypass congestion on tollways than to rideshare and bypass congestion on pre existing HOV facilities. Alternatively, paying users might choose to

¹ Value pricing can take the form of an add-lane(s), take-lane(s), or convert-lane(s) project; can replace, complement, or compete with high-occupancy vehicle facilities; may offer pricing that is set at one level, varies with time-of-day, or varies with observed; and may include discounts for high-occupancy vehicles, transponder owners, or frequent users.

² The terms traveler, user, commuter, and decision maker are used interchangeably to mean the person making the trip.

rideshare more frequently because they can share the cost of the toll, plus they can bypass congestion on both tollways and pre existing HOV segments. Some paying users might choose to rideshare with at least two other people for the additional benefit of the HOV-3+ discount.

Route of travel. It is expected that commuters with a high value of time (VOT) would be more likely than others to pay to use one of the tollways because for these commuters the value of time saved may be greater than the price of the toll. However, some commuters who perceive safety and comfort benefits may prefer tollway travel over free travel regardless of the value of the time savings. Also, commuters with a bias against tolls may favor other methods of avoiding congestion, like shoulder period travel or ridesharing, choosing to use the free lanes even when the price of the toll is low. In terms of choosing between the SR-91 tollway and the Eastern tollway, paying customers must compare travel times and tolls and also evaluate the SR-91 tollway requirement for electronic payment and a pre paid account.

Location of intermediate stop(s). Travelers may choose locations near tollways for intermediate stops (e.g., gym, coffee, groceries, child care).

Trip chaining. Users who pay may link trips together for better value for their toll dollar. Alternatively, users who were previously motivated by congested travel conditions to link their trips may decide to make separate trips using tollways.

Trip frequency. Commuters may travel to work more frequently instead of telecommuting knowing they can pay to bypass congestion.

Transponder ownership. Travelers who want access to both tollways or desire the convenience of automatic toll collection will be motivated to acquire a transponder. Those who don't want to pre pay tolls, wish to avoid carrying charges, or perceive

transponders as an invasion of privacy may choose not to own a transponder and not to use the SR-91 tollway.

Auto ownership. Most travelers in the SR-91 corridor have a vehicle at their disposal. In this corridor, it is doubtful that value pricing would provide a new incentive for multiple vehicle ownership. It is also doubtful that households with a commitment to ridesharing would decide to forego an extra vehicle because of value pricing.

Employment location. Commuters may seek workplaces conveniently located near the tollways.

Residential location. The option to pay to bypass congestion may enable households to locate farther from their workplaces. Some commuters may be motivated to relocate closer to the tollways.

Identifying potentially affected choices helps to establish a framework for travel demand analysis. Understanding the relationships among the choices is more difficult. Most of the choices listed above are made before the trip begins. One exception is route choice. A traveler may depart with the notion of using a free route, for example, and later “divert” to one of the tollways in response to traffic reports, observed congestion, or feelings of being pressured for time.

Whereas the classical “four-step” approach to regional travel demand estimation follows a certain hierarchical sequence, the current study assumes that mode, time, and route are jointly decided. The hierarchical sequence of the four-step model is represented in Figure 3.1 on page 21. This well-known procedure for estimating link volumes and transit ridership was originally developed to meet the supply-oriented planning needs of the 1950s and 1960s. Its limitations make it a weak choice for value pricing and other policy measures for demand management.

One limitation is that the four-step approach treats each trip as an independent entity, effectively ignoring the potential for the attributes of one trip in a linked series to affect decisions for the entire chain. Another limitation is that the time choice dimension is missing. In best practice regional models, factors that vary depending on the level of congestion are applied to the trip tables from the mode choice step to produce a set of trip tables for different time periods (unpublished paper by M. Replogle and D. Reinke, Jan. 1998). Time can also be addressed in the trip assignment step by loading work trips first and then shifting non work trips to peak shoulder periods as link volumes approach capacity (R. Milam, personal communication, May 29, 2003). While useful for some applications, these ad hoc methods for incorporating the missing time dimension are inadequate for analyzing peak spreading in the context of value pricing (18).

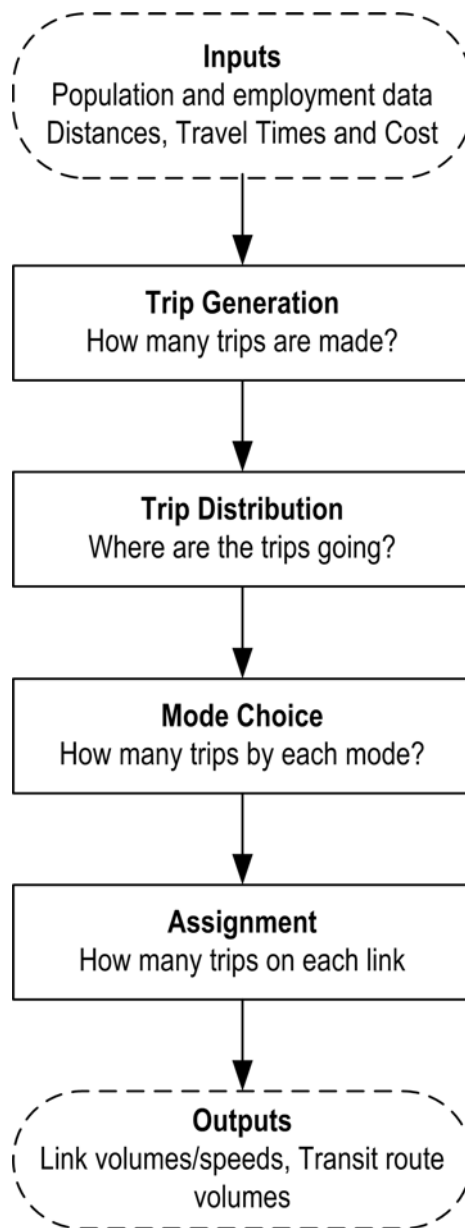


Figure 3.1 Classical four step approach to regional travel demand estimation

Activity-based model frameworks, which are starting to produce some practical tools for demand analysis, are considered to be more suitable than traditional trip-based models for addressing detailed timing issues and interdependent events and for addressing issues

of induced trips and suppressed demand (19). An activity-based approach aims for a more holistic framework derived from differences in lifestyles and activity participation among the population. One of the features of this emerging paradigm is the use of household and person classification schemes based on differences in activity needs, commitments, and constraints (20). In the context of developing activity-based forecasting tools, the current study makes an important contribution by investigating the implications for value pricing of classifying persons based on differences in their constraints regarding the feasibility of certain travel alternatives. The expected benefit is that a better understanding of choice set and decision making will lead to more accurate behavior modeling.

4 TRAVEL BEHAVIOR MODELS

From the previous discussion, it can be seen that value pricing has the potential to affect a wide range of choice behaviors. It has been suggested that the observed effects on mode, route, and time usages will depend on the attributes of the pricing project and the characteristics of the users and that for a given user, a constraint on any of these short-term choices can affect the others. In terms of further establishing a framework for analyzing short-term choice behavior, these observations point to a disaggregate approach where individual users jointly decide mode, time, and route. The condition that all available combinations of mode, time, and route are not necessarily considered for choice is examined here in conjunction with a review of theory and practices for travel demand modeling.

In general, disaggregate models aim to explain between-person differences in travel behavior in terms of socioeconomic and locational characteristics of individuals and their households (21). These models are commonly applied to mode choice and other dimensions of travel that can be characterized by a small number of alternatives (22, p. 276). Discrete choice analysis has also been applied to problems involving multidimensional choice sets, where members of the set of alternatives are combinations of underlying choice dimensions (e.g., mode plus route or route plus time). Development¹ of a choice model is typically based on the hypothesis that in a choice situation, an individual associates a value with each evaluated alternative. This value is commonly referred to in the travel demand literature as “utility” and the individual is assumed to choose the alternative that yields the greatest utility or, alternatively, the least

¹ The terms model development, model estimation, and model calibration are used interchangeably to mean the use of empirical data to determine how independent variables like travel time and income are related to dependent variables like the choosing of an alternative.

disutility. For a given trip, the disutility² of a travel alternative is a function of the trip, the attributes of the alternative, and the characteristics of the decision-maker.

For a given population, the process of *estimating* a disaggregate choice model is the process of determining how independent variables like travel time and income are related to dependent variables like the choosing of a given alternative. Model estimation requires theoretical assumptions about the choice process plus a sample of observed travel decisions complete with socioeconomic data that describe the decision makers and attributes that describe the travel alternatives.

Mathematical Models of Travel Choice Behavior

Individual choice behavior is often characterized by the availability of particular travel alternatives, a traveler's perceptions of these alternatives, and his preferences for the attributes of the alternatives (23). The basic approach to the mathematical theories of individual preferences is that of microeconomic consumer theory (22, p. 39). The link between the theory of individual behavior and the corresponding mathematical models is usually established in the following manner. Consider a decision maker n who faces discrete alternatives $j = 1, \dots, J$. The set of all available alternatives is the universal choice set M . C_n is the set of alternatives available to decision maker n , where C_n is a subset of M .

² The term disutility is used throughout this manuscript to correspond with the negative valuation of travel time and tolls.

Let each alternative in a set C_n be characterized by an evaluation measure (24):

$$U_{jn} = V_{jn}(z_{jn}, s_n, \beta_n) + \varepsilon_{jn} \quad (4.1)$$

where

U_{jn} = the total indirect disutility of alternative j for decision maker n ,

V_{jn} = a known function typically referred to as deterministic or systematic disutility,

z_{jn} = a vector of attributes of alternative j as they apply to the decision maker n ,

s_n = a vector of socioeconomic characteristics of decision maker n ,

β_n = an individual-specific taste parameter vector, and

ε_{jn} = an unobservable component of disutility (a random variable).

It is assumed that the decision maker operates upon the evaluation measures, U_{jn} , with decision rule D_n with the objective of choosing the most attractive alternative (25).

From this perspective, variability among decision makers with the same observed characteristics (s_n) can arise if the decision makers have different

- choice sets (C_n),
- decision rules (D_n),
- functional forms for deterministic disutility (V_{jn}),
- tastes (β_n), or
- error structures (ε_{jn}).

Each of these is described below, and it is shown that different assumptions regarding choice sets, decision rules, error structures, etc., results in different models.

Choice Sets

Choice set formation can be viewed as the process of establishing the set of feasible alternatives available to an individual decision maker. Standard discrete choice models consider the set of alternatives available to an individual to be known with certainty (26). A typical deterministic rule for specifying the choice set in the mode choice context is that an individual without a car and/or driver's license does not have the "drive alone" alternative in the choice set (27). The availability of the alternative can be simulated implicitly in the drive-alone mode choice model by introducing the car availability attribute in the disutility function. However, this confuses disutility attributes with availability attributes, so it is generally preferable to estimate a choice model based only on the available alternatives (28). Non physical or subjective constraints such as informational, psychological, and social restrictions, which may also establish the infeasibility of specific alternatives, typically go unobserved (26).

Some behavior theorists have suggested that one or more alternatives, which in principle are available, may not be fully considered for a particular choice or circumstance (29). Simon (1) refers to the "considered subset" as the subset of objectively available alternatives that the decision maker actually considers for choice. When deterministic rules are insufficient for finding the considered choice set, the choice set is probabilistic to the analyst. A variety of probabilistic choice set generation models have been proposed to estimate the availability of each alternative. For a review see Ben-Akiva and Boccara (30); for an example see Swait and Ben-Akiva (26).

This study addresses the challenge of unobservable choice sets by using survey data to identify the set of behaviors revealed in each user's history of travel activity in the SR-91 corridor. As a direct consequence of the manner in which the choice problem is specified, a user's own set of revealed behaviors maps to one of only four possible choice sets. The model includes two modes (solo or rideshare), two time periods (peak or shoulder), and two routes (free or tollway). The choice of whether to use a free route

or a tollway is assumed to depend on the set of mode and time period alternatives considered by the decision maker. The four possible considered sets are {solo, peak}, {solo, rideshare, peak}, {solo, peak, shoulder}, and {solo, rideshare, peak, shoulder}. The full details of the choice set estimation procedure are given in Sections 9 and 10, wherein the risk of potentially underestimating the considered choice is assessed.

Decision Rules

Decision-making is a cognitive process by which the attributes of the alternatives are synthesized and an observable response is achieved. Transportation planners generally assume that choice decisions are made in a compensatory manner. When making a mode choice decision, for example, it is generally assumed that travelers make trade-offs between attributes like travel time and cost. Examples include additive choice models involving multiple regression, discriminant analysis, and the logit function (31). In these forms of the choice process, a change in one or more attributes can be compensated by a change in the opposite direction in one or more of the other attributes (32).

An alternative assumption is that attributes are evaluated in a sequential manner beginning with the attribute the individual considers most important and ending with the attribute that the individual considers least important. A third notion is that when an individual evaluates an alternative for a given attribute, he compares the alternative against some standard he is willing to accept and rejects alternatives not meeting the standard (32). Non compensatory views of the choice process are found in dominance models, maximax and maximin models, lexicographic choice functions, and conjunctive and disjunctive choice criteria (31). The most general specification is to have the internal mechanism for processing information and arriving at a choice vary among individuals. Because this is difficult to do, the typical approach is to choose one decision rule and assume that it is used by the entire population.

The hypothesis of utility maximization (or disutility minimization), which is used extensively in the development of predictive models of human behavior (22, p. 38) and is employed in this study, is based on compensatory offsets. Under this hypothesis, the attractiveness of an alternative expressed by a vector of attributes is reducible to a scalar, which is a measure of disutility that the decision maker attempts to minimize through his or her choice. A utility model always predicts that the alternative with the lowest disutility will be chosen, regardless of whether that alternative's disutility is much smaller or only slightly larger than the disutilities of the other considered alternatives.

The current study assumes a two-stage process, where a non compensatory process is used in the first stage to shape the considered choice set. Next, it tests the hypothesis that the compensatory mechanism for making a choice varies among the four pre defined segments of the population. It is expected that differences in compensatory offsets among attributes may lead to noteworthy differences in disutility measures, which should help explain observed differences in choice. Basically, the proposal is one of using a market segmentation approach in model estimation. To this author's knowledge, the existing literature contains no examples of using choice set as the basis for market segmentation.

Functional Form of the Choice Function

The form of the deterministic portion of the disutility function reflects presumptions about how the independent variables contribute to the disutility of the alternative. Typically, this function includes a vector of attributes of the alternative as they apply to the decision maker (z_{jn}) and a vector of parameters (β) that are the coefficients of the attributes or coefficients of transformations of one or more attributes. The function may also include a vector of socioeconomic characteristics of the decision maker (s_n), which effectively allows different disutility structures for different identifiable groups of decision makers (24, p. 13).

Most choice models have a linear form, in which the variables have independent additive effects, or a product form that is readily transformed to linear, in which complete interaction is presumed (33). Functions that are linear in parameters are computationally convenient in that it is relatively easy to estimate the unknown parameters. A linear form is adequate for the purposes of this research, given that the primary aim is to uncover differences in compensatory choice behavior among the segments rather than to develop a predictive model. The objective is to test the hypothesis that the systematic disutility associated with tollway alternatives varies between the four segments.

An important issue in deciding the form of the disutility function is whether the estimated parameters have any relation to the specific alternatives. One assumption is that the person making the choice perceives the attributes themselves rather than the alternative being considered and that two distinct alternatives that have the same attributes would be evaluated equally (i.e., they would have the same disutility). This assumption leads to an alternative-generic model where all alternatives are described by the same function and the parameters are the same for all alternatives. As an illustration, consider a mode choice model for the choice of auto A versus rail R. Suppose that the independent variables in the choice function are travel time, TT_A and TT_R , and travel cost, TC_A and TC_B . The alternative-generic specification would result in the following choice function for decision maker n :

$$V_{jn} = \beta_1 * TT_{jn} + \beta_2 * TC_{jn} \quad (4.2)$$

where β_1 and β_2 are constant parameters, and $j = A$ or R .

Another assumption is that the influences of the attributes vary from one alternative to another. For example, this study explores the hypothesis that time spent in rideshare alternatives may have greater disutility than time spent in solo alternatives. As shown in

Kanafani (17, p. 196), an assumption like this leads to the alternative-specific model with the following choice function:

$$V_{jn} = \beta 1_j * TT_{jn} + \beta 2_j * TC_{jn} \quad (4.3)$$

In addition, the alternative-specific choice function may include dummy variables or constant terms that are specific to each alternative:

$$V_{jn} = \beta 1_j * TT_{jn} + \beta 2_j * TC_{jn} + \alpha_j \quad (4.4)$$

where α_j is an alternative-specific constant term that will have different values for A and R. It is common practice to label one of the alternatives as the base alternative and to set its alternative-specific constant equal to zero. In this way, the alternative-specific constant may be interpreted as the average disutility of the unobserved attributes of the j -th alternative, relative to the base alternative.

Most mode choice studies have found that one or more mode-specific effects must be included in the model and have concluded that unquantifiable social factors that influence people's choice among modes are a major cause of this. Specifying these constants is an indication that the observed variables are inadequate to entirely explain the choice behavior (24). Important variables must often be omitted due to lack of data or measurement problems (22). One measurement challenge is characterizing the actual choice set. Consider the decision maker who does not really consider the j -th alternative. In this case, the average disutility of the unobserved attributes relative to the base alternative is so large as to result in a zero probability for selecting the j -th alternative.

Tastes

In travel demand modeling, it is assumed that an individual's choice represents an expression of his preferences for the attributes of the considered alternatives under the circumstances in which the choice is made. This assumption is demonstrated in the disutility function, where the coefficients express the value, or importance, that decision makers place on observed attributes. One assumption is that these coefficients vary over decision makers, thereby reflecting differences in taste, as in Equation 4.4. In many cases, tastes vary for reasons that are not observable or identifiable, just because people are different (22, p. 29). For example, commuters who routinely oversleep their alarm clocks are probably more concerned about the travel time of an alternative relative to its other attributes than commuters who are not challenged in this way.

Traditional choice models like the logit model can capture taste variations only within limits. Tastes that vary systematically with respect to observed variables can be incorporated by interacting attributes of the alternatives with characteristics of the individual as in $V_{jn} = \beta 1_j * TT_{jn} + \beta 2_j * TC_{jn} + \beta 3_j * Male_n * TC_{jn} + \alpha_j$ where $Male_n$ is a gender dummy variable equal to 1 if the decision maker is male and otherwise is 0. Gender is just one characteristic of the individual that may be associated with taste. Other characteristics of the individual that may be relevant include socioeconomic factors such as income, as well as situational and attitudinal factors (34). Tastes that vary with unobserved variables, or purely randomly, cannot be explicitly incorporated (35).

If the degree of interaction among variables is assumed to be different for different segments of the population, then it is possible to use *market segmentation* to develop a distinct model for each subgroup (33). This is typically done for different socioeconomic groups (e.g., gender, income). The current study explores taste variations within market segments based on choice set. It is plausible that the same constraints that influenced the formation of the choice set may also influence the

valuation of considered alternatives. Alternatively, the situation of choosing from a larger or smaller choice set may itself influence the valuation of considered alternatives. The current study does not go so far as to discover which of these theories is more evident. Rather, the goal is simply to identify differences between the groups.

Error Structures

In empirical applications, the analyst does not know the disutilities with certainty and they are therefore generally treated as random variables that take on different values with certain probabilities. Random influences can stem from inconsistent choice behavior due to lack of information about the attributes of the alternatives, stochastic fluctuations in the manner in which the attributes are perceived, or the absence of a rational and consistent decision rule (17, p. 119). Another reason for adopting a stochastic model is that it is usually not possible to include in the deterministic disutility function V_{jn} all of the variables that can possibly influence choice (17, p. 122).

The random disutility of an alternative (U_{jn}) is expressed as a sum of deterministic disutility (V_{jn}) and a random variable representing an unobserved disturbance or error term (ε_{jn}). The error term is assumed to follow some probability distribution and the deterministic component of disutility is assumed to represent the mean disutility (36, 17). There is no guarantee that $E[U_{jn}] = V_{jn}$. Varying the assumptions about the distributions of the unobservable component ε_{jn} leads to different choice models. An example follows.

Multinomial Logit

Most operational models assume a functional form of the disutility function that is linear in the parameters and with an additive random variable representing an unobserved

disturbance or error term, ε_{jn} (36). The probability of that alternative j in C_n is chosen by decision maker n is given by

$$P_n(j) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \quad (4.5)$$

The choice probability $P_n(j)$ is viewed as the analyst's statement of the probability that for decision maker n , the disutility of alternative j will be less than the disutilities of all other considered alternatives. In order to solve for the choice probabilities, the analyst must assume a probability distribution for the error terms, ε_{jn} . When the ε 's are assumed to be independently and identically distributed (IID) Gumbel variates, then Equation (4.5) reduces to the well-known multinomial logit (MNL) formula:

$$P_j = \frac{e^{V_{jn}}}{\sum_{\forall j \in C_n} e^{V_{jn}}} \quad (4.6)$$

There have been numerous applications of the MNL model, and computer applications for estimating the vector of unknown parameters using maximum likelihood estimation are readily available (36). This familiar choice model is used in this study. The statistical software package known as Stata is used to estimate the parameters.

An important property of the MNL model is the independent from irrelevant alternatives (IIA) property. The IIA property states that for any individual, the ratio of the probabilities of choosing two alternatives is independent of the availability or attributes of any other alternative. This limits the responses to transportation changes that can be predicted by the MNL model. This peculiarity of the MNL model is rooted in the assumption that the error terms, ε 's, are independent random variables and correlations among the disutility functions are not captured (36).

Multidimensional Choice Sets

In some discrete choice situations, the members of the set of feasible alternatives are combinations of underlying choice dimensions (22, p. 276). For example, in the context of a value pricing problem, it may be desirable to define a two-dimensional choice set in which each element of the set is a combination of mode and route. From a modeling perspective, both systematic and unobserved disutility can be partitioned to include components attributable to each dimension, individually, and/or a component specific to the combination of the two dimensions (22, p. 285). Using the mode and route example, this can be written as

$$U_{mr} = V_m + V_r + V_{mr} + \varepsilon_m + \varepsilon_r + \varepsilon_{mr}, \quad \forall (m, r) \in C_n \quad (4.7)$$

where

U_{mr} = the total disutility of the element of C_n consisting of mode m and route r ,

V_m = the systematic component of disutility common to all elements of C_n using mode m ,

V_r = the systematic component of disutility common to all elements of C_n using route r ,

V_{mr} = the remaining systematic component of disutility specific to the combination (m, r) ,

ε_m = the unobserved component of the total disutility attributable to mode m ,

ε_r = the unobserved component of the total disutility attributable to route r , and

ε_{mr} = the remaining unobserved component of the total disutility specific to the combination (m, r) .

In situations where the elements of the underlying choice sets that form the multidimensional choice set have separate unobserved components, the disutilities of the

multidimensional alternatives are not independent and one of the assumptions underlying the joint logit model is violated. It is generally agreed that the multinomial logit model should not be applied indiscriminately to choice contexts involving multiple mode-route combinations and the like, and that the nested logit model may be a suitable alternative (22, p. 322). Williams and Ortuzar (37) compared the nested and multinomial logit for application to the situation described in Equation 4.7 with the goal of determining the conditions of similarity under which serious mis-specification errors resulted. They found that the multinomial logit model performed reasonably well under a wide range of assumptions and was “considerably more robust than [they] had anticipated.” The authors summarized their favorable findings regarding MNL with the following statement:

The problems of similarity, or correlation, once exposed are now appearing considerably less formidable in theory and practice. Circumstances can occur in which the nested logit models of a particular design become suspect, particularly when a complex web of similarities exists between the attributes and the alternatives.

For the current study, the relative merits of using a nested logit model versus a simpler model are explored in the next section (Section 5) in conjunction with a review of literature on empirical choice models estimated for value pricing.

5 EMPIRICAL CHOICE MODELS

Whereas the previous section gives the theoretical basis for travel choice modeling, the current section reviews the literature for empirical choice models that have been estimated for value pricing. Various researchers have used data from a value-priced corridor to identify the determinants of tollway use (38,39), measure the value of travel time (13,40,41), and explore related behaviors¹ (42,43). In contrast to these studies, the current study points to choice set as an indicator for compensatory choice behavior. In doing so, new insight is delivered regarding between-person differences in willingness to trade money for travel time savings, or shift ridesharing behavior or time of day relative to route.

In preparing to estimate a behavior model for value pricing, the existing literature offers little guidance in terms of the most appropriate ‘tree structure’² or mathematical form for the model. As shown in Figure 5.1, the current study makes use of a simple tree structure for the choice of mode, route, and time – one in which each choice is represented by just two alternatives and all combinations are available. In order to establish an appropriate frame of reference for discussing this model and describing the work of other researchers, a wider range of choice dimensions and alternatives is presented in Figure 5.2 and Figure 5.3.

The material in this section is an important contribution to the literature in that it presents for each choice dimension a set of candidate model specification that a modeler might consider.

¹ Parkany (42) studied how travelers use traffic information to make their route choice. Golob (43) explored linkages between attitudes and behavior.

² The term tree structure refers to a graphical method of enumerating choice alternatives and depicting relationships between multiple choice dimensions.

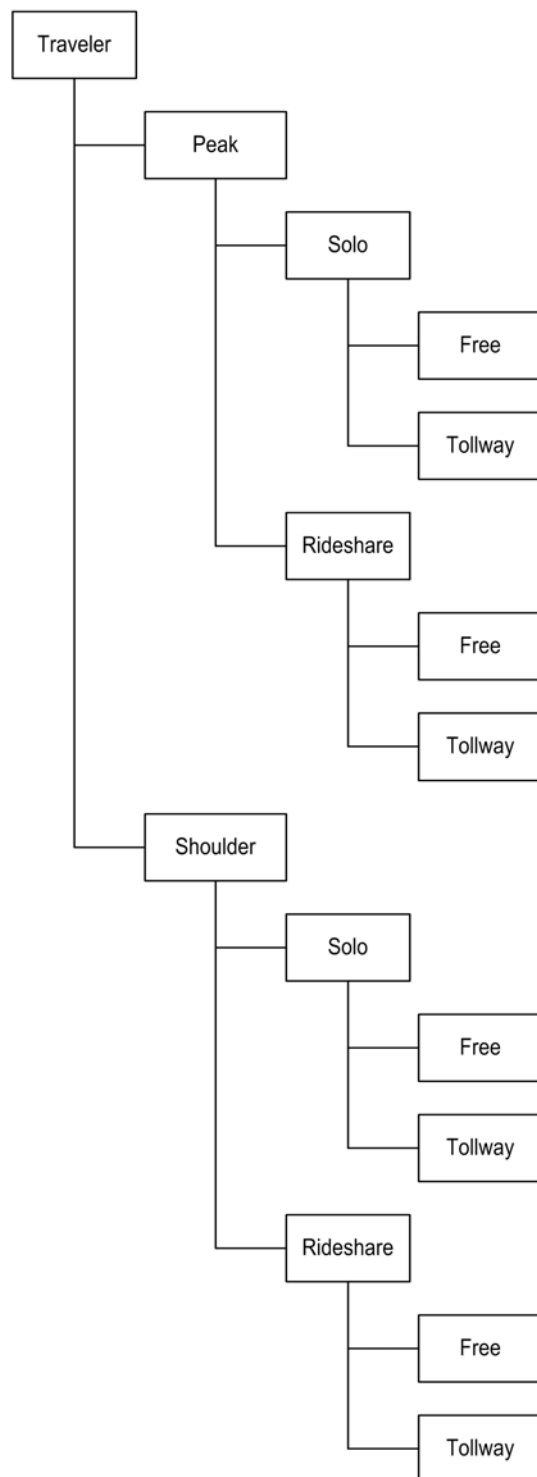


Figure 5.1 Simple tree structure for choice of mode, route, and time

Overview of Choices and Alternatives in Value Pricing

Mode, route, time of day, and transponder ownership are among the choices for which disaggregate choice models are most commonly applied in value pricing. The usual approach is to characterize one or more of the choice dimensions by a small number of alternatives. In a managed lanes setting like SR-91, where tolled lanes and free lanes share the same highway, the traveler's choice of route is obviously a key dimension. For a differential pricing project, like those in Lee County, Florida, time of day is clearly the more relevant choice. Whenever tolls vary over the peak period, or discounts are given to certain users, or transponder equipment is associated with access, it becomes desirable to represent certain *combinations* of transponder ownership, mode, route, or time of day as separate alternatives in a multidimensional choice model.

SR-91 is one example of a value-pricing project for which a multidimensional choice model may be appropriate. For the SR-91 project, Figure 5.2 characterizes four choice dimensions and dozens of alternatives associated with morning travel. Most of the value-pricing choice models that have been estimated for SR-91 consider some *subset* of the tree structure shown here. The tree in Figure 5.2 is a *representative* framework for analyzing choice behavior and is not intended to include every dimension and alternative that might be investigated. An alternate framework is shown in Figure 5.3, where the lowest level includes mode-route options instead of route-time options. Both tree structures are useful in that they arrange a variety of choice dimensions and alternatives in a meaningful way. For example, Figure 5.2 is specifically constructed to reflect the condition that travelers must have a transponder in order to use the SR-91 tollway. As such, there are more route-time combinations available to transponder owners than for non owners. Figure 5.2 also reflects the condition that HOV-3+ users are priced differently from other users on the SR-91 tollway but not on the Eastern tollway.

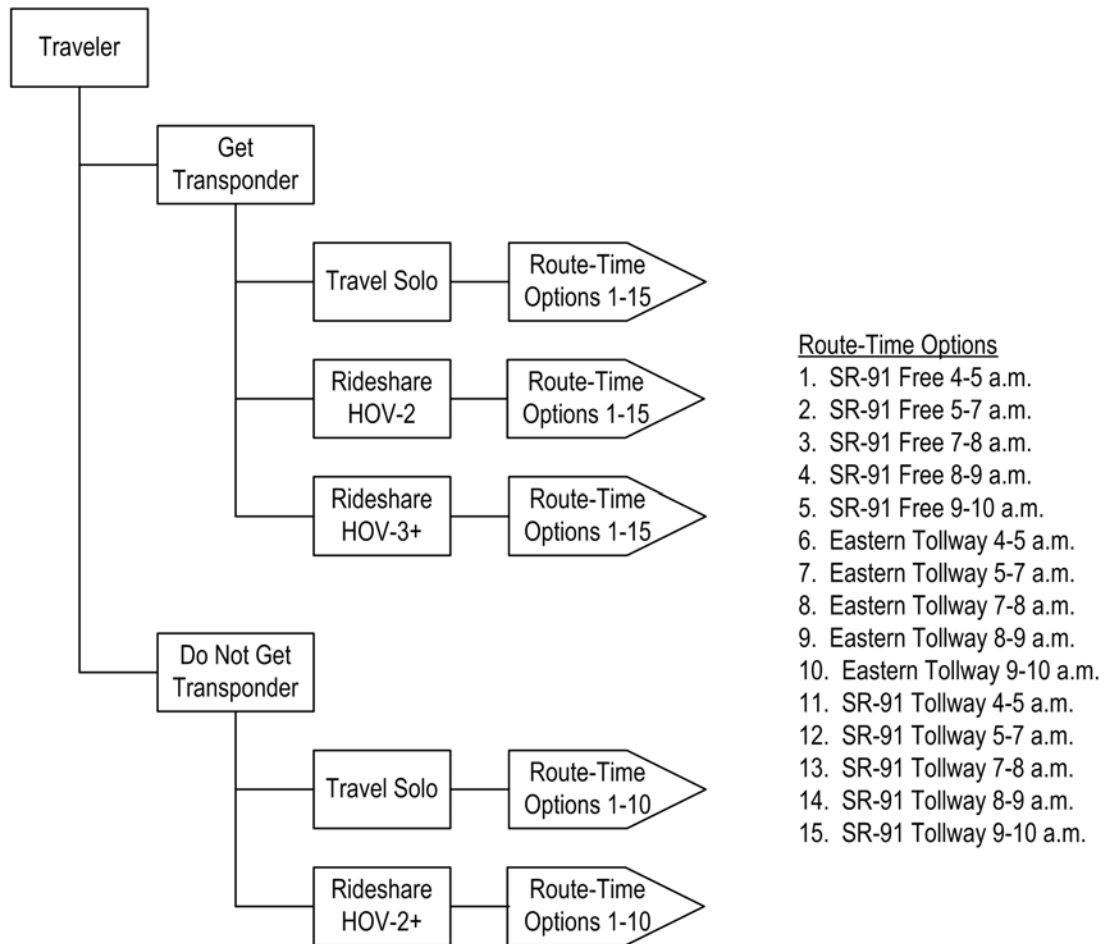


Figure 5.2 Detailed tree structure for choice of transponder, mode, route, and time

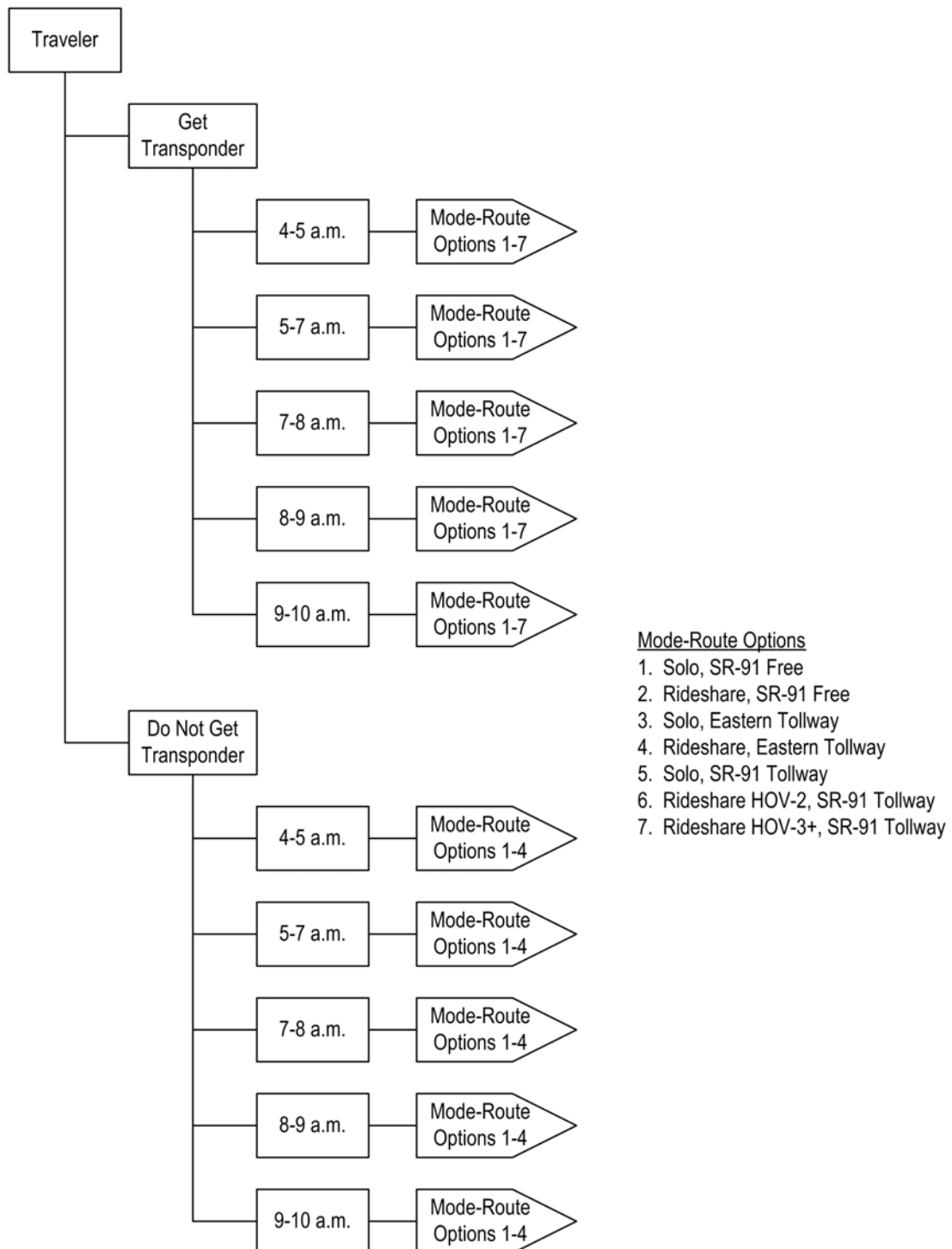


Figure 5.3 Alternate tree structure for choice of transponder, mode, route, and time

Either figure provides a useful starting point for analysis. It is up to the analyst to define the alternatives and choose the form of the model. The choices in Figure 5.2 can be modeled in various ways: (1) a sequential model with the route-time choice being conditional on mode and transponder ownership, (2) a simultaneous model with $3 \times 15 = 45$ mode-route-time combinations for transponder owners $2 \times 10 = 20$ mode-route-time combinations for non owners, or (3) a nested model with mode choice at the upper level (perhaps with transponder ownership being treated as an inherent part of route choice). Similarly, the choices in Figure 5.3 suggest a different set of models, including a nested model with *time choice* at the upper level. Clearly, there are many possibilities, which multiply as opportunities to condense or expand the alternatives associated with each choice dimension are considered. Some applications of these opportunities are explicitly discussed below.

Transponder Ownership

Consider the choice of transponder ownership. In the SR-91 corridor, having a transponder and setting up the associated financial account is a necessary condition for using the SR-91 tollway and generally makes it easier to use the Eastern tollway. In the I-15 corridor in San Diego, the same is true for solo drivers wishing to access the tollway. In some choice models, installation of a transponder is treated implicitly as part of the route choice. Other models treat transponder installation as an explicit choice dimension. Lam and Small (40) and Yan et al. (41) experimented with both types of models and concluded that income and gender affect the willingness to undertake the fixed cost of installing a transponder. Golob (43) found that age and gender affected willingness to establish an account. Still, these studies do little to explain why so many people who have transponders make different decisions from day to day whether to use them. Based on a model that accounts only for the travel time for the 10-mile study section of SR-91 and not the full trip, Lam and Small (40) suggest that work-hour flexibility and total trip distance seem to influence the *daily* route choice decisions of

transponder owners. A conflicting report in Sullivan (44) found work schedule flexibility to be unrelated to the level of SR-91 tollway use.

Table 5.1 compares the different ways transponder choice might be specified. The first Transponder Choice specification (labeled XPC1) is the option of treating transponder ownership as an inherent aspect of route choice. Several examples of XPC1 are given in the literature, where the disadvantages of setting up a financial account are typically reflected in the alternative-specific constant for the tollway alternative. One such model is given by Li (38).

Table 5.1 Different Ways to Characterize Transponder Choice

Transponder Choice 1 (XPC1)	Transponder Choice 2 (XPC2)	Transponder Choice 3 (XPC3)
Implicit	Own Don't Own	Regular Account Club Account Employer-Paid Account Don't Own

The second Transponder Choice specification given in Table 5.1, XPC2, is the simplest way to treat transponder ownership as an explicit choice and is found in Yan et al. (41) and Lam and Small (40). Brownstone et al. (13) assumed that travelers who want to use the I-15 tollway have already obtained a transponder (XPC1) and tested this assumption with a nested logit. In a similar manner, the current study assumes that any traveler who wants to use the SR-91 tollway or desires convenience in using the Eastern tollway has already obtained a transponder (XPC1). Among commuters who travel the study corridor in the peak direction, this study finds that 64.4% of women and 52.9% of men own a transponder.

A more realistic approach for transponder choice, not found anywhere in the literature, is to use something like XPC3 to represent the different types of financial accounts that might be used (44). According to Sullivan (45), approximately 18% of SR-91 transponder holders do not personally pay for their use (10% are employer-paid, 5% are funded by a family member, friend, or someone else, and 3% are paid for by a combination of sources). In addition, approximately 12% of the 618 qualifying³ transponders in the Cal Poly study sample are linked to club accounts which provide discounts to frequent SR-91 tollway users (45).

This author's decision to use XPC1 instead of XPC2 is one in a series of decisions to constrain the number of choices and choice sets to be enumerated. Like all empirical studies of this type, this one faces constraints in terms of the size of the sample and the available network data. This is made apparent in a paper presented by this author at the 81st Annual Meeting of the Transportation Research Board in 2002. This paper describes a preliminary analysis in which the same data is analyzed for eight choice sets (twice as many as is featured in this dissertation). It soon became apparent that the study sample was not large enough to support model estimation for all eight market segments.

Some commonly employed techniques for narrowing the scope of the choice problem include defining one or more choice dimensions exogenously or implicitly, enumerating some but not all feasible options, and defining a single alternative to be characteristic of a set of competing alternatives. This section makes an important contribution to the pricing literature by enumerating for each choice dimension a set of candidate specifications (like the one for transponder ownership given in previously Table 5.1) and then using them to compare and contrast the various empirical models available in the value pricing literature.

³ Only CPTC-issued transponders can be linked to club accounts. CPTC is the California Private Transportation Company – private developer and operator of the SR-91 tollway through 2002.

The particular model featured in this study is unique among those in the value pricing literature in that mode, route, and time of day choice are modeled jointly in a single model. This represents a key motivating factor for this research, which is to allow for the condition that mode, route, and time are *simultaneously* evaluated. To this author's knowledge, no other model of mode *plus* route *plus* time is given for value pricing. In order to estimate a discrete choice model separately for each choice set group within the constraints of the available dataset, this author found it necessary to minimize the number of discrete choices to be enumerated. Keeping the universal choice set to a minimum delivers an important benefit in terms of limiting the number of subsets of it to be defined as considered choice sets. The motivation for limiting the number of considered choice sets is to prevent the sample from becoming too fragmented in the market segmentation to be useful for model estimation.

In accordance with the preceding discussion, this modeler approached the task of specifying the choice problem by first considering for each choice dimension, the absolute minimum specification. The following demonstrates that in the case of the State Route 91 value priced corridor the various choice dimensions can be adequately characterized using no more than two alternatives. Future research can build upon the work of this dissertation by amassing a larger sample and expanding the model specification to include more alternatives and perhaps explicitly represent the choice to acquire a transponder.

Mode Choice

Table 5.2 gives different ways for specifying mode choice. Brownstone (13) estimates a mode-route choice model for I-15 using Mode Choice specification #1 (MC1). This is a logical choice for the I-15 project given that SOVs (single occupancy vehicle) are the only users who pay and cost-sharing among the occupants is not an issue when vehicle

occupancy is one. Li (38) offers a logistic regression model of route choice (SR-91 tollway vs. SR-91 free) with vehicle occupancy as one of the independent variables (MC3 – see Table 5.2), but ignores the differential pricing for HOV-3+ users by failing to include the cost of the toll in the model. Yan et al. (41) recently estimated a nested logit model for 15 combinations of mode (MC2), transponder (XPC2 – see Table 5.1), and route (RC3 – see page 49) in which the per-person toll entered as the toll in dollars divided by the number of people in the vehicle (less than or equal to three).

Table 5.2 Ways to Specify Mode Choice – Some Examples

Mode Choice 1 (MC1)	Mode Choice 2 (MC2)	Mode Choice 3 (MC3)	Mode Choice 4 (MC4)
SOV	SOV	Occupancy = 1	SOV
HOV	HOV-2	Occupancy = 2	HOV-2
	HOV-3+	Occupancy = 3	HOV-3+
		Occupancy = 4	Bus
		Occupancy = 5	Bike
			Telecommute

Intuitively, a mode choice specification that captures the number of occupants (like MC2 or MC3) is appealing wherever discounts or toll sharing arrangements define unique mode-route alternatives in terms of perceived cost or travel time. Unfortunately, little is known about traveler perceptions of per-person toll costs, especially when formal cost-sharing is absent or when ridesharing involves trips with children. Sullivan (44) suggests that HOV commuters are more likely than SOV commuters to choose the SR-91 tollway because the opportunity to split the toll among occupants is a factor in route choice. Yet the evaluation report to Caltrans finds no significant differences between

groups who cost-share and groups that do not, either in terms of their likelihood for using toll facilities for recently reported trips or in their reported frequency of toll facility use (45, p. 110).

When the SR-91 toll lanes first opened in December 1995, HOV-3+ users were permitted to use the SR-91 tollway free of charge as long as the vehicle was equipped with a transponder. Approximately 2 years later, in early 1998, the policy was modified from “transponder-owning HOV-3+ users travel free” to “transponder-owning HOV-3+ users pay 50% of the posted toll.” Five years later, in mid-2003, the policy was reversed (presumably because the 50% toll discount was not enough incentive for ridesharing) and HOV-3+ users were again permitted to travel free of charge, except eastbound 4:00 – 6:00 p.m. Sullivan (44) reports that despite the 50% discount enjoyed by HOV-3+ users in fall 1999, no significant difference in SR-91 tollway use between HOV-3+ and HOV-2 users was observed. This observation is doubly confounding given that the additional occupant among which to split the toll would perhaps in and of itself be enough to see a difference between HOV-3+ and HOV-2 use. If Li (38) is correct that each additional occupant increases the likelihood of using the SR-91 tollway by 92%, it would seem unlikely that the difference between HOV-2 and HOV-3+ would not be statistically significant – unless there are diminishing returns as occupancy increases above two.

As explained, the available information fails to give clear guidance to the modeler how to best represent the decision maker’s perceived cost of the toll. Consider a household-based HOV3 rideshare group comprised of one driving adult and two children. The “usual” approach for representing the perceived per-person cost of the toll is to use MC2, compute the 50% discount toll for HOV-3+ users, and then divide by the number of occupants. For a posted toll of \$3.00, this approach gives \$0.50 as the perceived per-person cost for the decision-maker, which is \$1.00 less than the true \$1.50 out-of-pocket cost for this individual. A different approach for representing the perceived per-person

toll cost is used in the current study. The study approach uses MC1, ignores the discount, and divides the dollar cost of the toll by 2 if the mode is HOV, regardless of the number of occupants. Table 5.3 examines various ridesharing arrangements and compares the estimated per-person cost under the two approaches.

Table 5.3 Actual vs. Estimated Out-of-Pocket Toll Cost

Occupant 1 (Decision Maker)	Occupant 2	Occupant 3	Cost-Share	Out-of-Pocket (\$)	Perceived (\$) Usual Approach	Perceived (\$) Study Approach
Adult	Child		No	\$3.00	\$1.50	\$1.50
Adult	Adult		No	\$3.00	\$1.50	\$1.50
Adult	Adult		Yes	\$1.50	\$1.50	\$1.50
Adult	Child	Child	No	\$1.50	\$0.50	\$1.50
Adult	Adult	Child	No	\$1.50	\$0.50	\$1.50
Adult	Adult	Child	Yes	\$0.75	\$0.50	\$1.50
Adult	Adult	Adult	No	\$1.50	\$0.50	\$1.50
Adult	Adult	Adult	Yes	\$0.50	\$0.50	\$1.50

As shown for HOV-2 users, there is no difference between the study approach (MC1 and divide by 2 for HOV) and the usual approach (MC2 and divide by the number of occupants). For HOV-3 users, both approaches are equally inconsistent in terms of approximating the out-of-pocket cost. A better treatment for behavior modeling would be to explicitly account for the presence and type of cost-sharing. Otherwise, the study approach is acceptable in that it appears to account for per-person toll costs at least as well as the alternative.

A fifth option for mode choice specification not given in Table 5.2 is the option of omitting mode choice altogether. This approach is based on the assumption that mode choice is exogenous to the subject choice decision (e.g., route choice). Parkany (42), Li (38), Lam and Small (40), and Yan et al. (41) all estimated simple route choice models for the SR-91 corridor that are conditional on vehicle occupancy (mode), time of day, and transponder ownership. Lam and Small (40) found that compared to the route choice only model, the route and mode choice model had a 28% higher implied value of time, with \$19.22 per hour from the route choice only model and \$24.52 per hour for route and mode choice model. For mode and route choice, the authors test nested and joint logit and concluded that joint logit is an adequate description. For the nested logit, it was reported that the coefficient of inclusive value had an implausible sign and did not fit significantly better under a likelihood ratio test.

Route Choice

When the SR-91 toll lanes first opened in December 1995, the Eastern tollway did not exist. The Eastern tollway first became available to motorists in October 1998 and continues to operate in direct competition with the SR-91 tollway for certain trips to Irvine and southern Orange County. Beyond the SR-91 corridor is a network of carpool lanes accessible by vehicles with two or more persons. Because of the widespread availability of carpool lanes, there are plenty of origin-destination pairs within the study region for which the following is true.

Peak period traveler #1, who shares a ride but doesn't use the SR-91 tollway, enjoys a shorter travel time⁴ than peak period traveler #2, who drives solo and doesn't pay. Peak traveler #3, who drives alone and pays, also enjoys a shorter

⁴ Ignoring passenger pick-up and drop-off times.

travel time compared traveler #2. Peak period traveler #4, who shares a ride and uses the SR-91 tollway has the shortest travel time of all.

Thus, the SR-91 tollway competes directly with the SR-91 free lanes and the Eastern tollway (for some trips) and also indirectly with the greater network of carpool lanes (whenever a decision maker switches between being traveler #1 to being traveler #3). At the same time, the SR-91 tollway complements the existing carpool lanes (whenever a decision maker switches from being traveler #1 to traveler #4). Choice models that examine only the portion of the trip coincident with the tollway facility, which is all but Yan et al. (41) and the current study, are unable to capture these effects. Table 5.4 lists different ways of specifying route choice, irrespective of whether the travel time measurements represent the full trip. Yan et al. (41) uses Route Choice specification #3 (RC3), which differentiates between the SR-91 and Eastern tollways. Working with the same data as Yan et al. (41), Li (38) chooses RC4 to characterize the route choice, failing to distinguish between the SR-91 free route and the Eastern tollway, which are two distinctly different route alternatives. Lam and Small (40) represent two choices with RC2 using data collected before the Eastern tollway opened.

Table 5.4 Ways to Characterize Route Choice – Some Examples

Route Choice 1 (RC1)	Route Choice 2 (RC2)	Route Choice 3 (RC3)	Route Choice 4 (RC4)	Route Choice 5 (RC5)
Free Tollway	SR-91 Tollway SR-91 Free	SR-91 Tollway SR-91 Free ETC Tollway	SR-91 Tollway Other	SR-91 Tollway SR-91 Free ETC Tollway SR-60 Other

The current study uses MC1. This is accomplished for the 1999 condition, which includes the Eastern tollway, by aggregating the travel time and cost attributes of the two tollway facilities to represent a single generic tollway route alternative. For any origin-destination pair and any combination of mode and time, a representative value of time (e.g., \$15 per hour) is used to compare the travel time and toll attributes of the two competing tollways. In a majority of the cases, it turned out that the lower-cost tollway was also the shortest travel time tollway and it was not necessary to apply an assumed value of time to identify the preferred tollway. The described procedure ignores the condition that a pre paid transponder account is required for the SR-91 tollway, but not the Eastern tollway. As such, transponder ownership is treated as an inherent aspect of route choice and the preferred tollway is identified based only on travel time and toll. Further details regarding the procedure for aggregating travel times and tolls by route is given in Section 6.

Like Yan et al. (41), the current study uses total trip travel time to distinguish between a path that traverses a tollway and then continues on general-purpose highway lanes and a path that traverses a tollway and then continues using carpool lanes.⁵ During peak hours, the path that continues using carpool lanes generally results in a shorter travel time.

Still another approach for examining the route choice dimension not given in Table 5.4 is to use, as the dependent variable in a route choice model, the *frequency* with which a user chooses one alternative over another. Sullivan (44) reports highly selective behavior in the SR-91 value-priced corridor, where the proportion of commuters who report using the SR-91 tollway has increased over time. Parkany (42) investigated this phenomenon with a set of SR-91 route choice models for which the dependent variable takes on one of four frequency-of-use values (never use, use infrequently, use often, and use always) and is nested with the decision to get a transponder at the upper level.

⁵ Because they only measured the travel time for the 10-mile study, the models estimate by Lam and Small (40) are lacking in this respect.

Another example is Burris and Pendyala (39), who estimated a model for differential pricing where the dependent variable reflects the frequency with which the user switches to shoulder period travel.

Time of Day

When characterized by a small number of intervals, time is readily used in a discrete choice model regarding the timing of the trip. Of course, the modeler must decide which time intervals to represent and must also specify the associated stage of the trip to reference (e.g., the departure time, the arrival time, or the time a given landmark is passed). Table 5.5 gives some examples of the different ways a modeler might specify the time intervals of interest. Burris and Pendyala (39) estimated a time choice model for differential pricing based on Time Choice specification #1 (TC1). The Lee County project features one discount toll offered during four peak shoulder intervals; two shoulder periods in the morning and two shoulder periods in the evening. Participation in the Lee County value pricing is associated with traversing the bridge during any shoulder period, thereby defining two time intervals in the form TC1.

Table 5.5 Ways to Characterize Time of Day Choice – Some Examples

Time Choice 1 (TC1)	Time Choice 2 (TC2)	Time Choice 3 (TC3)	Time Choice 4 (TC4)
Peak	Before the Peak	Before the Peak	4:00 – 5:00 a.m.
Shoulder	Peak	Early Peak	5:00 – 6:00 a.m.
	After the Peak	Peak of the Peak	6:00 – 7:00 a.m.
		Late Peak	7:00 – 8:00 a.m.
		After the Peak	8:00 – 9:00 a.m.
			9:00 – 10:00 a.m.

None of the value pricing modeling studies in the literature have been extended to jointly model mode, route, *and* departure time. Brownstone (13) was forced by insufficient data to assume that departure time is fixed, even though time of day is the primary determinant of travel time and cost for the I-15 tollway. Lam and Small (40) developed a route (RC2) and time (TC4 with 30-minute intervals) choice model, but were limited by unknown travel times for parts of the trip beyond the 10-mile study section and also by the assumption of exogenous mode choice. Yan et al. (41) estimated a rather complex nested logit model of time (TC3), transponder (XPC2), and route (RC3) choice, also conditional on mode (MC2), and concluded that people will alter their transponder acquisition and route choices much more readily than they will change their schedules. The resulting model indicates that increasing the peak-of-the-peak tolls by 10% results in overall shifts out of this time period by just 0.49% in the a.m. and 0.73% in the p.m. (41).

For the modeler, a decision for specifying the time choice dimension depends in part on the extent to which hourly variations in traffic conditions and tolls affect travel behavior. This is investigated for the SR-91 corridor in Sullivan (44), but yields conflicting interpretations. Sullivan establishes that highly time-differentiated toll schedules, which began in September 1997, were not accompanied by much flattening of the peak-period traffic distributions. And while Sullivan (44) reports a strong correlation between tollway patronage and time-of-day-dependent travel time savings in June 1997, a substantially looser relationship is depicted for January 1999 in the full report (45, p. 48). By January 1999, a sharp peaking of travel time savings between 4:00 p.m. and 6:30 p.m. is associated with mild peaking of tollway patronage. Furthermore, it has been demonstrated that perceptions of driving comfort and greater safety⁶ motivate some travelers to use the SR-91 tollway in situations where the expected value of time savings

⁶ Reliability of travel time is a distant and third motivation for off-peak use of the SR-91 tollway.

is less than toll paid. All told, these findings suggest that in the SR-91 corridor, travel behavior is *not* terribly sensitive to hour-by-hour changes in travel times and tolls.

For the current study, the primary focus is on combinations of mode, route, and time that are distinctly different from one another in terms of user perceptions of cost and travel time. For this purpose, TC1 is adequate. TC1 is accomplished by specifying the bounds for the morning and evening peak and averaging the measurements for the corresponding time intervals. The travel time measurements supplied by Cal Poly has the morning period divided into four 1-hour intervals and one 2-hour interval as follows: 4:00 – 5:00 a.m., 5:00 – 7:00 a.m., 7:00 – 8:00 a.m., 8:00 – 9:00 a.m., and 9:00 – 10:00 a.m. For this study, TC1 is achieved by averaging the measurements associated with 4:00 – 5:00 a.m. and 9:00 – 10:00 a.m. to represent the shoulder period and averaging⁷ the other measurements to represent the peak. These and other procedures for handling the network data (measurements of travel times and tolls) are given in the next section.

⁷ Weighted to account for the one 2-hour period.

6 NETWORK TRAVEL TIMES AND TOLLS

The principal methodology for this research is a choice-set segmentation approach to disaggregate travel choice modeling. Choice models can be estimated on the basis of revealed choice behavior when the analyst understands the characteristics of reporting decision makers and the attributes of the considered alternatives. The next section (Section 7) introduces the travel survey from which information about the decision makers and their trips was obtained. The current section describes the procedure for estimating the travel time and cost attributes of the considered alternatives. The basic procedure is one of taking a larger set of skim matrices¹ and aggregating the travel time estimates across routes and across time periods in order to produce a smaller set of skim matrices.

For the central work of this study, the choice situation is a joint mode-time-route choice where each of the three choice dimensions is a binary choice. As shown in Table 6.1, the two mode alternatives are solo and rideshare, the two time alternatives are peak and shoulder, and the two route alternatives are free and tollway. Thus, the choice modeling requires consistent estimates of travel times and tolls for the eight joint alternatives $j = 1, \dots, 8$.

¹ A “skim” matrix or “skim tree” is a term that refers to a matrix containing the travel times between all combinations of origin and destination zones.

Table 6.1 Eight Mode-Time-Route Alternatives

$j =$	Travel Choice	Mode	Time	Route
1	Endure	Solo	Peak	Free
2	Carpool	Rideshare	Peak	Free
3	Pay	Solo	Peak	Tollway
4	Carpool & Pay	Rideshare	Peak	Tollway
5	Shift	Solo	Shoulder	Free
6	Shift & Carpool	Rideshare	Shoulder	Free
7	Shift & Pay	Solo	Shoulder	Tollway
8	Sift & Carpool & Pay	Rideshare	Shoulder	Tollway

The data available for this study includes 66 skim matrices generated by Cal Poly² to represent all combinations of two modes, eleven time periods, and three routing options as shown in Table 6.2. (Referring back to the various models described and labeled in the previous section, this is a model of the form MC1-TC4-RC3.) Given that the current study requires just eight skim matrices, a multi step procedure is needed to aggregate across the two toll routes and across time. The task presents several challenges, which are defined in the discussion that follows. These include missing data, unknown preferences between the two tollways, and allowing a single travel time attribute to represent a multi hour time period. Ultimately, 66 sets of TT_{mtr} s are reduced to 8 sets of $TTime_j$ s, where TT_{mtr} and $TTime_j$ are in minutes and the variables j , m , t , and r are as defined in Table 6.1 and Table 6.2.

² This work, which is described immediately following Table 6.2, was performed by Dr. Edward Sullivan, Joseph Gilpin, and Kari Blakely.

Table 6.2 Cal Poly's 66 Mode-Time-Route Alternatives

$m =$	Mode	$t =$	Time	$r =$	Route
1	Rideshare	1	4:00 – 5:00 a.m.	1	Eastern tollway
2	Solo	2	5:00 – 7:00 a.m.	2	SR-91 free
		3	7:00 – 8:00 a.m.	3	SR-91 tollway
		4	8:00 – 9:00 a.m.		
		5	9:00 – 10:00 a.m.		
		6	2:00 – 3:00 p.m.		
		7	3:00 – 4:00 p.m.		
		8	4:00 – 5:00 p.m.		
		9	5:00 – 6:00 p.m.		
		10	6:00 – 7:00 p.m.		
		11	7:00 – 8:00 p.m.		

Network Modeling

The study area includes 150 cities in Los Angeles, Orange, Riverside, and San Bernardino counties, divided into 99 traffic analysis zones. The geometry of the interstates, highways, and arterials was coded by tracing scanned images of maps. Special lane types and connections were coded using data from the Southern California Association of Governments and the Thomas Bros. Guide. TP+/VIPER software was used to create different versions of the network, where each version represented prevailing traffic conditions for a different time-of-day period. Traffic data were assembled in fall 1999 by collecting time-dependent link speeds from the Freeway Performance Management Project and Los Angeles Real Time Traffic websites, the Caltrans District 8 and District 12 congestion monitoring programs, and floating car runs

conducted by Cal Poly researchers. Most carpool and toll links were coded using the uncongested freeway speed of 65 mph. An exception is the section of the Eastern tollway closest to SR-91, where a lower speed was used to reflect congested conditions at certain times of the day.

After coding the network, the Cal Poly team obtained route-specific O-D travel time estimates by temporarily “excluding” competing tollways from the network and estimating the shortest travel time path. For example, estimates specific to the SR-91 tollway were sought by setting the travel time variable for the Eastern tollway to a prohibitively high value. But, because the SR-91 free route was not similarly excluded, the travel time for the SR-91 tollway was not *necessarily* computed. There are no intermediate exits or entrances along the length of the SR-91 tollway. As a result, the SR-91 free route can be a faster path for trips to and from zones adjacent to the toll facility. Under these conditions, tollway travel times are missing from the dataset and all that is known to the analyst using the Cal Poly data is that the O-D travel time for the SR-91 tollway path is greater than or equal to the O-D travel time estimated for the SR-91 free path.

Prior to aggregating the travel time data, it is desirable to have *specific* estimates for both the SR-91 tollway and the Eastern tollway for all trips; even for trips to and from zones adjacent to tollways. The missing travel times for the Eastern tollway (TT_{mt1}) and SR-91 tollway (TT_{mt3}) are estimated by applying an inflation factor to the SR-91 free travel time (TT_{mt2}) as follows: $TT_{mt1} = 1.15 * TT_{mt2}$ and $TT_{mt3} = 1.05 * TT_{mt2}$. The designated criteria for selecting the respective values for these inflation factors was to replace travel time estimates known to be incorrect with travel time estimates that reflect the presumed ordinal relationship in the level of service afforded by the three routes, which is

$$TT_{mt1} > TT_{mt3} > TT_{mt2}.$$

The Cal Poly team obtained *mode*-specific O-D travel time estimates by temporarily “excluding” carpool lanes from the network and estimating the shortest travel time path. For rideshare trips, the home end origin zone is the location where the last passenger was picked up and the home end destination zone is the location where the first passenger was dropped off. Thus, the travel time estimates do not include the time to pick up and drop off passengers. For a majority of the O-D pairs, peak period rideshare travel times are shorter than solo travel times because carpools lanes are available throughout Orange County and beyond.

Cal Poly’s TP+/VIPER model is a scientific basis for estimating the travel times for the trips reported by users who participated in the travel survey. The travel times from this model represents the best available data for the current study. A sample set of travel times for a single O-D pair and direction of travel is given in Table 6.3. This table shows that the estimated travel time from Zone 12 in Irvine eastbound in the p.m. to Zone 74 in Murrieta ranges from low a of 61.69 minutes when traveling rideshare on the Eastern tollway between 2:00 and 3:00 p.m. to a high of 92.84 minutes when traveling solo on SR-91 free between 5:00 and 6:00 p.m. For each O-D pair in the study area, there is a unique set of travel times just like the set shown here.

Table 6.3 Travel Times from Zone 12 (Irvine) to Zone 74 (Murrieta)

Time	Rideshare			Solo		
	Eastern Tollway (min)	SR-91 Free (min)	SR-91 Tollway (min)	Eastern Tollway (min)	SR-91 Free (min)	SR-91 Tollway (min)
2:00 – 3:00 p.m.	61.69	66.14	64.87	62.60	67.44	65.77
3:00 – 4:00 p.m.	65.18	73.15	67.08	73.25	84.04	76.51
4:00 – 5:00 p.m.	70.41	78.96	68.52	80.78	91.59	78.21
5:00 – 6:00 p.m.	70.67	78.08	68.52	81.69	92.84	79.91
6:00 – 7:00 p.m.	65.31	71.91	67.65	71.53	82.30	76.37
7:00 – 8:00 p.m.	63.74	70.72	66.81	65.30	72.28	67.32

Aggregating by Route

For each O-D pair represented in the travel survey, a two-step process is used to aggregate the travel times and tolls to the desired level. The current study requires eight travel time estimates for each O-D pair; one for each combination of two modes, two routes, and two time periods. (Referring back to the various models described and labeled in the previous section, this is a model of the form MC1-TC1-RC1.)

In the first step, attributes specific to the SR-91 and Eastern tollway route alternatives are “aggregated” to arrive at a set of attributes for the generic Tollway route alternative. The two time-toll combinations are examined against an assumed mean value of travel time of \$15.00 per hour³ in order to determine which of the two tollways would be the preferred tollway. When the shorter travel time tollway is the more expensive tollway, it is necessary to account for the assumed value of time in determining which of the two

³ The choice for the mean value of time is loosely based on model estimation for the same corridor as reported by Lam and Small (40).

tollways would be the preferred tollway. This is a simple task of comparing the two sets of time-toll combinations against the assumed value of time. For the sample data presented in Table 6.3 the results of this step are demonstrated in Table 6.4. The procedure for comparing time-toll combinations is described below.

Table 6.4 Free vs. Tollway Travel Times & Tolls, Eastbound p.m. Travel (O-D Pair 12-74)

Time	Rideshare			Solo		
	Free (min)	Tollway (min)	Toll (\$)	Free (min)	Tollway (min)	Toll (\$)
2:00 – 3:00 p.m.	66.14	61.69	\$3.25	67.44	62.60	3.25
3:00 – 4:00 p.m.	73.15	65.18	\$3.25	84.04	73.25	3.25
4:00 – 5:00 p.m.	78.96	68.52	\$3.35	91.59	78.21	3.35
5:00 – 6:00 p.m.	78.08	68.52	\$3.35	92.84	79.91	3.35
6:00 – 7:00 p.m.	71.91	65.31	\$3.25	82.30	71.53	3.35
7:00 – 8:00 p.m.	70.72	66.81	\$2.25	72.28	67.32	2.25

To the extent that attributes other than travel time and the posted toll affect preferences between the two tollways, the described procedure may yield an erroneous estimation. For example, a given individual may view the requirement to carry a transponder on the SR-91 tollway as a deterrent against this alternative and may therefore favor the Eastern tollway even though it is not otherwise worth it to him to spend an extra \$1.00 to save just 3 minutes. For the current example, the consequence of this is to mistakenly assign the attributes of the non preferred tollway, thereby underestimating the perceived toll by \$1.00 and overestimating the perceived travel time by approximately 3 minutes. An erroneous estimation also results if the user's true value of time is greater than the assumed value.

Aggregating by Time

In the second step of the process, attributes specific to time periods that comprise the middle four hours (3:00 – 7:00 p.m.) are aggregated to arrive at one set of attributes for the peak time period, and the remaining values are aggregated to arrive at one set of attributes for the shoulder time period. In both cases, a simple average is computed and the results for the sample data are shown in Table 6.5. The same results are presented again in Table 6.6. The only difference between Table 6.5 and Table 6.6 is that the figures are rearranged to correspond with the format used at the start of this section in Table 6.1. In Table 6.6, the variables $TTime_j$ and $Cost_j$ represent the travel time and cost attributes of alternative j , respectively.

Table 6.5 Travel Times & Tolls, Eastbound p.m. Travel (O-D Pair 12-74)

	Rideshare			Solo		
	Free (min)	Tollway (min)	Toll (\$)	Free (min)	Tollway (min)	Toll (\$)
Shoulder time	68.43 ⁴	64.25	2.75 ⁵	69.86	64.96	2.75
Peak time	75.53 ⁶	66.88	3.30 ⁷	87.69	75.73	3.30

The procedure of computing simple averages is apparent by inspection of Table 6.4 and Table 6.5 and the accompanying footnotes. For a given mode-route combination, a single travel time attribute for peak period travel is identified to represent travel conditions over a 4-hour period (3:00 – 7:00 p.m.). Similarly, a single travel time

⁴ $(66.14 + 70.72)/2 = 68.43$ minutes

⁵ $(\$3.25 + \$2.25)/2 = \$2.75$

⁶ $(73.15 + 78.86 + 78.08 + 71.91)/4 = 75.53$ minutes

⁷ $(2 \times \$3.25 + 2 \times \$3.35)/4 = \$3.30$

attribute for shoulder period travel is identified to represent travel conditions for the combination of two non consecutive hours that ‘straddle’ the peak (2:00 – 3:00 p.m. and 7:00 – 8:00 p.m.).

Table 6.6 Travel Times & Tolls Rearranged, Eastbound p.m. Travel (O-D Pair 12-74)

$j =$	Travel Choice	Mode	Time	Route	$TTime_j$ (min)	$Cost_j$ (\$)
1	Endure	Solo	Peak	Free	87.69	0
2	Carpool	Rideshare	Peak	Free	75.53	0
3	Pay	Solo	Peak	Tollway	75.73	\$3.30
4	Carpool & Pay	Rideshare	Peak	Tollway	66.88	\$3.30
5	Shift	Solo	Shoulder	Free	69.86	0
6	Shift & Carpool	Rideshare	Shoulder	Free	68.43	0
7	Shift & Pay	Solo	Shoulder	Tollway	64.96	\$2.75
8	Shift & Carpool & Pay	Rideshare	Shoulder	Tollway	64.25	\$2.75

The aggregate values in Table 6.5 and Table 6.6 are interpreted as being *characteristic* of each defined alternative and do not necessarily correspond to a specific travel time that a given user might actually experience. For example, consider the Shift & Carpool alternative ($j = 6$). For this particular mode-route combination (Rideshare-Free), the shoulder period travel time (68.43 minutes) is *less than* travel time given for the 1-hour period preceding the peak (66.14 minutes, 2:00 – 3:00 p.m.) and *greater than* the travel time given for the 1-hour period following the peak (70.72 minutes, 7:00 – 8:00 p.m.). In the choice modeling, the effect on sampled users who are more likely to choose early

shoulder travel over late shoulder travel will be to over estimate the travel time of the shoulder period alternatives. This is a consequence of the decision to aggregate by route and time to fit the data to the specified universal choice set with just eight alternatives. In a future choice set study with a larger sample, it would be useful to consider more time periods and explicitly represent both tollways.

The above described procedure delivers the desired result, which is to arrive at consistent estimates of travel time and cost for the eight alternatives, across all O-D pairs. These estimates are the quantitative parameters of the choice problem characterized in this study. The values of the parameters are intuitively pleasing and are believed to be an appropriate depiction of how the members of the study population actually distinguish among the available alternatives. The following relationships, which can be seen in Table 6.6, are believed to represent user knowledge about study period travel. The parenthetical portions of the below statements are representative of a typical user's 'intuition' about study period travel.

1. The Endure alternative has the greatest travel time.
2. For a given mode, tollway travel is faster than free travel (but more 'expensive').
3. For a given route, peak rideshare travel is faster than peak solo travel (but less 'convenient').
4. For a given route, shoulder rideshare travel is not much faster than shoulder solo travel (and is less 'convenient').
5. For a given mode-route combination, shoulder travel is faster than peak period travel (but less 'convenient').

A goal of this study is to discover the extent to which these perceptions vary among groups with different choice sets (see Section 14). Consider, for example, the estimates

in Table 6.6 and the travel time for the Carpool alternative ($TTime_2 = 75.53$ minutes) compared to the Pay alternative ($TTime_3 = 75.73$ minutes). In the context of a logit model of choice behavior, the two choice probabilities are equal when the disutility of the dollar cost of the toll is equivalent to the disutility of the inconvenience of ridesharing relative to solo travel. Rather than assume everyone chooses from the same universal choice set, the current study aims to explicitly account for individuals who have a zero probability of sharing a ride (see Sections 9 and 10). Doing this should prevent the estimation procedure from misrepresenting, for individuals who have a non-zero probability of ridesharing, their preferences among these alternatives. In addition, the preferences of users who consider ridesharing and not shoulder period travel are compared with the preferences of users who consider the full choice set, and the condition that one group may be more willing than the other to trade money for travel time savings is explored.

7 THE SURVEY

This research uses data from a fall 1999 travel survey conducted for Caltrans to explore the behavior of peak period travelers in the SR-91 corridor. The data were used by Cal Poly to investigate travel behavior and public opinion and, in conjunction with researchers at University of California at Irvine (U.C. Irvine), develop several choice models (41). The survey produced an extensive data set, which is used in this study to explore aspects of choice behavior that are beyond the scope of the original Caltrans-sponsored study. This section describes the survey and sampling procedures.

The survey targeted current weekday travelers who use the corridor between 4:00 and 10:00 a.m. or between 2:00 and 8:00 p.m., as well as former users. Former users are persons who traveled the corridor in 1997 (2 years prior to the survey) but have since stopped. These former users responded to special questions about why they no longer use the corridor. The surveys were conducted by telephone and involved three different subsamples:¹

1. Persons contacted using the random phone-dial technique and drawn from surrounding areas in proportion to the geographic distribution of corridor commuters (random dial subsample; N = 645).
2. Persons who also participated in an earlier 1996 travel survey of corridor commuters, having been identified through license plate observations on SR-91 (panel subsample; N = 348).
3. Persons identified through recent license plate observations on SR-91 and the Eastern tollway (new plates subsample; N = 730).

¹ A fourth subsample consisting of persons who participated in travel surveys of SR-91 commuters conducted by U.C. Irvine researchers in 1998 was not considered because it was too small (N = 65) and the sampling regime was too different from that of the other samples.

The panel and new plates subsamples consist of persons observed using the corridor on weekdays during study periods and traveling in the peak directions, which are westbound in the a.m. and eastbound in the p.m. The samples were drawn from the SR-91 tollway, SR-91 free lanes, and Eastern tollway in proportion to their traffic volumes. The panel sample was obtained in 1996 by Cal Poly students who drove SR-91 and recorded license plates by speaking the license plate numbers into voice recorders. The new plates sample was obtained in 1999 by parking a university van equipped with a high-resolution mast-mounted camera at key locations along SR-91 and the Eastern tollway and video recording license plates. In both cases, the license plates were sent to the California Department of Motor Vehicles for name and address matching. Phone numbers were then obtained from a commercial address-telephone number matching service, and private vehicle owners were informed by mail and contacted by telephone.

The random dial sample was obtained by randomly sampling phone numbers from exchanges throughout the commuter-shed² of the study corridor in proportion to the number of trips from the different cities observed in the 1996 survey. Persons who were using the corridor at the time of the survey or who commuted in the 2 years prior to the survey were asked to participate.

The survey instrument shown in Appendix A was developed by Sullivan and Mastako, and phone contacts were conducted by Strategic Consulting & Research of Irvine, California, a survey research subcontractor. The household members who travel the corridor were identified, contacted, and asked to participate in telephone interviews lasting 10 to 15 minutes. Current travelers gave trip reports supplemented by questions on the use of the tollways, perceptions about the tollways, and changes in travel behavior compared to 2 years ago. The trip reports identify the origin, destination, time, purpose, mode, and route of each trip. Travelers were asked about their most recent study period

² The commuter-shed is the geographic region in which the majority of corridor users live.

trip³ on Monday through Thursday and second study period trip if different. The interviews concluded with questions about personal and household characteristics.

Data Reduction

The survey generated 1,723 interviews including 645 from the random dial subsample, 348 from the panel subsample, and 730 from the new plates subsample. This study examines only the subset of interviews that reported a recent Monday through Thursday trip. Of the 1,138 interviews that reported a recent Monday through Thursday trip, a substantial number were discarded because the screening questions (questions 25 and 26 shown in Appendix A) failed to “weed out” reports of trips made outside the study period, trips that did not cross the Orange-Riverside county line, and trips that crossed the county line *opposite* to the peak travel direction (i.e., eastbound travel in a.m. is opposite to the peak direction). A total of 159 trip reports (14% of 1,138) were discarded because they were not the type of trip that the survey was designed to capture.

After considerable deliberation, Sullivan and Mastako settled on the phrasing of question 25, which reads:

During the past month, did you make any morning trips into Orange County between 4 a.m. and 10 a.m. on Monday through Thursday?

It was thought that phrase “... *into Orange County*...” was more likely to be correctly interpreted than a question asking about *westbound* trips that *crossed the county line*. Prior experience with the 1996 survey had demonstrated the difficulties associated with screening for the desired type of trip. The O-D portion of the fall 1996 survey included a similar quantity of intracounty trips (i.e., trips that did not cross the county line) and reverse-direction trips. Sullivan and Mastako hypothesized that users were unclear

³ A ‘study period trip’ is one made between 4:00 and 10:00 a.m. or between 2:00 and 8:00 p.m.

about the terms “eastbound” and “westbound” and were uncertain about the location of the county line. Unfortunately, the phrasing devised for the 1999 survey failed to improve the results.

An additional 36 trip reports (3.2% of 1,138) were discarded because they were incomplete in some material respect such as failure to report the destination, the mode, the route, or the departure time. Finally, one observation where the mode choice was transit and three observations where the mode choice was motorcycle were also removed from the database used in this dissertation on the basis that these observations may require special handling and needlessly complicate the model estimation.

As a result of the above described procedures, the study sample was reduced to 939 observations (368 random dial, 127 panel, and 444 new plates) that met the following criteria regarding the trip report:

1. Crossed the county line using SR-91,
2. Moved westbound in the a.m. or eastbound in the p.m.,
3. Traveled on a Monday, Tuesday, Wednesday, or Thursday,
4. Traveled westbound between 4:00 and 10:00 a.m. or eastbound between 2:00 and 8:00 p.m.,
5. Reported mode, route, origin, destination, and departure time, and
6. Traveled by private vehicle and not on a motorcycle.

The sample reduces to 797 trip reports (304 random dial, 112 panel, and 381 license plates) when respondents who did not divulge their household income are excluded. Household income has previously been shown to be associated with the choice between a free route and a tollway (41,40) and is expected to be an important variable in this study. Unfortunately, it is not uncommon for participants in a telephone survey to refuse

to give this type of personal information. Among the 939 users who gave a valid and complete trip description, 142 (15% of 939) chose not to reveal their household income even though “Refused” and “Don’t Know” were not among the pre-coded responses read aloud. For the model estimation portion of this study described in Section 13, trip reports from users who did not reveal their household income are labeled as incomplete and are set aside for model validation.

Sampling Considerations

The intent of the sampling procedure was to include two non random subsamples: (1) the panel subsample and (2) the new plates subsample. In both of these, the stated goal of the Cal Poly team was to select potential survey respondents separately from the solo and rideshare populations of commuters in order to achieve a sufficient number of rideshare respondents (45). When a *choice-based* sampling approach such as this is used and data from different populations are to be combined, it is usually necessary to apply *expansion factors*, or *weights*, in order to eliminate the bias from sampling different populations at different rates (46). In order to get unbiased estimates for the overall population of corridor users in this situation, the data from each rideshare respondent must be counted less than the data from each solo respondent, since each rideshare respondent in the choice-based sample represents a larger share of the actual rideshare population.

The random dial subsample is an independent data source from which to establish appropriate expansion factors for the choice-based subsamples. The proportion of solo and rideshare commuters in the random dial subsample should be representative of the actual universe of corridor commuters. Of course, the random dial technique is subject to biases including unlisted telephone numbers and unwillingness to participate in telephone surveys.

In the random dial subsample, 75% drove solo for their most recent trip and 25% shared a ride with at least one other person. Based on direct roadside observation in 1999, eastbound p.m. mode shares on SR-91 across all lanes are 76.1% solo and 23.9% rideshare and northbound p.m. shares on the Eastern tollway are 77.9% solo and 22.1% rideshare (45, p. 53). This similarity in mode shares gives credibility to the assumption that the random dial sample is an unbiased sample.

It is of interest to know if the other two samples can also be treated as random samples. The chi-square statistic is used to test the null hypothesis (H_0) that the solo mode share for choice-based subsample s , π_s , is the same as the solo mode share for the random dial subsample, π_0 . The alternative hypothesis (H_a) is that the mode shares are different ($\pi_s \neq \pi_0$). For the mode share example, the chi-square test statistic (χ_s^2) for subsample s , is:

$$\chi_s^2 = \frac{(n_s - E_s)^2}{E_s} \quad (7.1)$$

where

n_s = the number of solo observations in the choice-based subsample s and

$E_s = n_s \pi_0$, the expected number of solo observations in the choice-based subsample under H_0 .

Let α be the probability of a Type I error (rejecting H_0 when it is true). In this chi-square test, H_0 is rejected if χ_s^2 exceeds χ_c^2 , the tabulated critical value for $\alpha = 0.10$ level of significance and 1 degree of freedom ($\chi_c^2 = \chi_{(0.10,1)}^2 = 2.71$). Test results are given in Table 7.1, where the second and third columns compare the panel subsample

($s = 1$) and the new plates subsample ($s = 2$), respectively, against the random dial subsample. The cells in these columns give the corresponding π_s and χ_s^2 statistics. As shown, none of the tests of equal shares rejects the null hypothesis $H_0 : \pi_0 = \pi_s$ at the 10% level. Given that H_0 rather than H_a is the hypothesis of interest, it is not necessarily wise to accept the null hypothesis as fact just because it was not rejected. In other statistical tests, the alternative hypothesis is “proven” by contradicting the null hypothesis. In this test there is the potential for committing a Type II error in accepting H_0 (i.e., failing to reject H_0 when H_0 is false) (47). The implications for these tests are made apparent in the following discussion.

Table 7.1 Chi-Square Tests of Equal Mode, Time, and Route Shares

	Random Dial (N = 368)	Panel (s = 1) (N = 127)	New Plates (s = 2) (N = 444)
Mode: Solo vs. Rideshare	$\pi_0 = 75\%$	$\pi_1 = 67\%$ $\chi_1^2 = 1.17$	$\pi_2 = 72\%$ $\chi_2^2 = 0.78$
Time: Peak vs. Shoulder	$\pi_0 = 77\%$	$\pi_1 = 84\%$ $\chi_1^2 = 0.89$	$\pi_2 = 83\%$ $\chi_2^2 = 2.08$
Route: Free vs. Tollway	$\pi_0 = 64\%$	$\pi_1 = 66\%$ $\chi_1^2 = 0.89$	$\pi_2 = 64\%$ $\chi_2^2 < 0.01$

The tests of equal mode shares in the first row of Table 7.1 suggest that while the Cal Poly team originally set out to take two choice-based subsamples, the final mode-based sampling rates are equivalent to a simple random sample. Had the Cal Poly team spent additional time in the field, the target number of rideshare users in a given choice-based

subsample would have been met. As it stands, the panel subsample in particular may contain a smaller share of solo drivers than would be expected in a randomly drawn sample. Even though there is no statistical evidence to reject the hypothesis of equal shares, awareness of the choice-based sampling design is an argument for using expansion factors based on observed mode shares to combine observations. Generally speaking, there is no harm in applying expansion factors that appear to be unwarranted because the effect is to generate factors approximately equal to one.

A compelling argument in favor of expansion factors based also on observed *time* shares is revealed when considering the differences in time shares among subsamples as shown in the second row of Table 7.1. Further investigation into the Cal Poly sampling procedures revealed that observers were unable to include as many shoulder period users as intended in the choice-based subsamples. On approximately half of the assigned days for audio recording license plates for the panel sample, student workers either failed to make it to the field on time or ceased roving prior to the end of the study period. Following the video collection of license plates for the new plates sample, it was discovered that images recorded before sunrise and after sunset were not bright enough to permit license plate numbers to be viewed and recorded. These challenges in data collection explain the higher peak period shares and make an argument for expansion factors based on time shares.

Additional tests for socioeconomic differences between the random dial and choice-based subsamples also reveal a potential gender bias.⁴ The test for equal gender shares is shown in Table 7.2, where the one instance of rejecting the null hypothesis $H_0 : \pi_0 = \pi_s$ at the 10% level is flagged with an asterisk.

⁴ Similar tests for equal annual household income shares (< \$100,000 vs. \geq \$100,000) and equal age shares (30 – 49 years vs. other) were also conducted. For both subsamples the test failed to reject the null hypothesis of equal income shares $H_0 : \pi_0 = \pi_s$ at the 10% level. Only for the new plates subsample was the null hypothesis of equal age shares rejected at the 10% level.

Table 7.2 Chi-Square Tests of Equal Gender Shares

Attribute	Random Dial (N = 368)	Panel (N = 127, s = 1)	New Plates (N = 444, s = 2)
Male vs. Female	$\pi_0 = 63\%$	$\pi_1 = 61\%$ $\chi^2_1 = 0.04$	$\pi_2 = 73\%$ $\chi^2_2 = 12.99^*$

* $H_0 : \pi_0 = \pi_s$ is rejected at the 10% level.

As shown in Table 7.2, 73% of the new plates subsample is male compared to 63% of the random dial subsample. The hypothesis of equal gender shares is rejected at the 10% level with $\chi^2 = 12.99 > \chi^2_c = 2.71$. In the Cal Poly study⁵, the large difference in gender shares is attributed to a bias in the random dial sample based on the notion that among household members, women are more likely than men to answer the telephone (45, p.121). However, this does not explain the fact that there is no statistically significant difference between the random dial and panel subpopulations (63% and 61% male, respectively). Furthermore, the gender shares in the random dial subsample taken in 1999 (63% male) are approximately the same as the gender shares the 1996 population of SR-91 commuters (66% male) as reported in Mastako et al. (48) and Sullivan (49, p. 75). It does not seem plausible that the ratio between men and women in the SR-91 corridor would have changed dramatically in just 3 years. The evidence in the random dial sample suggests that among study period users in the SR-91 corridor the true proportion of men is 60% – 65% and not 70% – 75% as suggested by the new plates subsample.

⁵ Herein, the term “Cal Poly study” refers to *Continuation Study to Evaluate the Impacts of the SR-91 Value-Priced Express Lanes*, a Final Report to the State of California Department of Transportation, Principal Investigator: E. Sullivan, December 2000 (45).

It appears that a gender bias was inadvertently introduced in the new plates subsample (the reason for this is unknown) and that the cautious approach for handling the data is to maintain separate analyses for men and women. For this reason, the issue of equal mode and time shares, which was originally addressed in Table 7.1 with men and women combined ($N = 939$), is revisited for women ($N = 307$) and men ($N = 632$) separately in Table 7.3 and Table 7.4, respectively.

Table 7.3 Women: Chi-Square Tests of Equal Mode, Time, and Route Shares

	Random Dial ($N = 138$)	Panel ($s = 1$) ($N = 49$)	New Plates ($s = 2$) ($N = 120$)
Mode: Solo vs. Rideshare	$\pi_0 = 64\%$	$\pi_1 = 64\%$ $\chi^2_1 < 0.01$	$\pi_2 = 62\%$ $\chi^2_2 = 0.03$
Time: Peak vs. Shoulder	$\pi_0 = 78\%$	$\pi_1 = 84\%$ $\chi^2_1 = 0.66$	$\pi_2 = 89\%$ $\chi^2_2 = 6.57^*$
Route: Free vs. Tollway	$\pi_0 = 54\%$	$\pi_1 = 61\%$ $\chi^2_1 = 0.43$	$\pi_2 = 57\%$ $\chi^2_2 = 0.12$

* $H_0 : \pi_0 = \pi_s$ is rejected at the 10% level.

As shown in the second row of Table 7.3 above, the hypothesis of equal time shares between women in the new plates subsample and women in the random dial subsamples is rejected at the 10% level with $\chi^2 = 6.57 > \chi^2_c = 2.71$. Compared to the random dial sample, it appears that the new plates sample has a significantly larger share of peak period users and, conversely, a significantly smaller share of shoulder period users. This

is not unexpected given the previously described difficulties in collecting license plates in the early morning and late evening hours. The same trend is shown for men in the second row of Table 7.4 below, although the difference is not significant at the 10% level. By inspection of the first row of Table 7.4 for men below, it can also be seen that the share of solo drivers in each choice-based subsample is small compared to the share of solo drivers in the random dial subsample, although not significantly different at the 10% level.

Table 7.4 Men: Chi-Square Tests of Equal Mode, Time, and Route Shares

	Random Dial (N = 230)	Panel (s = 1) (N = 78)	New Plates (s = 2) (N = 324)
Mode: Solo vs. Rideshare	$\pi_0 = 82\%$	$\pi_1 = 69\%$ $\chi^2_1 = 1.59$	$\pi_2 = 75\%$ $\chi^2_2 = 2.03$
Time: Peak vs. Shoulder	$\pi_0 = 76\%$	$\pi_1 = 85\%$ $\chi^2_1 = 2.37 *$	$\pi_2 = 80\%$ $\chi^2_2 = 2.34 *$
Route: Free vs. Tollway	$\pi_0 = 70\%$	$\pi_1 = 69\%$ $\chi^2_1 = 0.01$	$\pi_2 = 67\%$ $\chi^2_2 = 0.51$

* $H_0 : \pi_0 = \pi_s$ is rejected at the 10% level.

Gender-Specific Expansion Factors

As discussed, the survey data used in this study involves three different subsamples. Among the subsamples, statistical evidence of unequal sampling relative to gender and time period is given in Table 7.2 and Table 7.3 respectively. Even though there is no

statistical evidence of unequal sampling relative to mode, it is not necessarily prudent to accept the null hypothesis of equal sampling as fact just because it was not rejected. This is especially true given the evidence of unequal sampling relative to time, the potential correlation between off-peak travel purposes and ridesharing, and the stated intent to include two subsamples in which rideshare users were over represented.

The analysis suggests that the cautious approach is to maintain separate analyses for men and women, and combine observations from the three subsamples only after applying expansion factors to the panel and new plates subsamples in accordance with the observed (gender-specific) *mode-time* shares, relative to the random dial subsample. The computed mode-time expansions factors are shown in Table 7.5.

**Table 7.5 Expansion Factors for Men and Women
Based on Mode-Time Shares**

	Random	Panel	Plates
MALE			
Rideshare-Shoulder	1.000	1.187	0.986
Rideshare-Peak	1.000	0.524	0.675
Solo-Shoulder	1.000	1.628	1.252
Solo-Peak	1.000	1.087	1.051
FEMALE			
Rideshare-Shoulder	1.000	2.486	2.029
Rideshare-Peak	1.000	0.799	0.803
Solo-Shoulder	1.000	0.947	1.988
Solo-Peak	1.000	1.023	0.921

The expansion factors in Table 7.5 are used to weight each observation in the usual multiplicative manner, thereby correcting for any over- or under sampling. Evidence of unequal sampling is given wherever the expansion factors are substantially different from 1. The factors less than 1 in the second row of Table 7.5 indicate that compared to the random dial subsample, men using rideshare in the peak period are over represented in the panel and plates subsamples. The factors greater than 1 in the fifth row indicate that women using rideshare in combination with shoulder period travel are under represented in the panel and plates subsamples. Applying the expansion factors in Table 7.5 to the sample data is the prudent thing to do and should reduce bias in the statistical analyses that follow.

8 PRELIMINARY ANALYSIS

The goal of this dissertation is to estimate a series of choice models and test for differences in taste among groups with different choice sets. The models are estimated based on data supplied by people who in fall 1999 made a recent peak-direction trip within the SR-91 value-priced corridor and participated in the telephone survey. The inputs to the model estimation include the attributes of the alternatives (see Section 6), the attributes of the decision-makers, and the chosen alternative. The latter two are examined here in this section using the method of cross tabulation¹. Men and women are analyzed separately for route choice in relation to age, education, and income. Choice combinations such as route choice given mode and mode choice given trip purpose are also examined. The primary objective is to provide a basis for model development by identifying potentially important predictor variables.

The analysis presented here mirrors portions of the work reported in Section 3 of the Cal Poly study (45)². However, the data are handled in a substantively different manner and different conclusions are reported. In the current study, observations from the three subsamples are combined only after applying gender-specific expansion factors based on observed mode-time shares. These expansion factors are given in the previous section in Table 7.5 on page 76. In the Cal Poly study, expansion factors were not used in combining data because it appeared to the team as if simple random sampling had been applied in each subsample (45, p. 119). However, the Cal Poly team did not investigate the possible under sampling of shoulder-period travelers, which was identified in the previous discussion. The share of females who traveled in a shoulder period is 21.7% in the random dial subsample compared to 16.3% and 10.8% in the panel and new plates subsamples, respectively. These differences are statistically significant at the 10% level

¹ Cross tabulation is a method for analyzing two or more categorical variables, like gender and mode.

² Highlights from Section 3 of the Cal Poly study appear in a recent TRB paper by Sullivan (44).

and should be accounted for using the expansion factors in Table 7.5 before the data are combined.

A second important difference between the current analysis and the Cal Poly study pertains to the relevant subset of survey data. Rather than limit analyses to the subset of commuters who reported peak-direction travel across the Orange-Riverside county line, the Cal Poly team examined the full sample. The problem with the Cal Poly approach is that full sample includes users with reverse and intra-county trips. The effect of this is illustrated in Table 8.1, which compares men and women in terms of transponder ownership. The left half of the table shows all responses (N = 1489), and the right half shows only responses from persons who reported a recent peak-direction trip across the county line (N = 939). As shown, gender differences are greater among peak-direction users, where 64.8% of women and 54.0% of men own a transponder³. It is hypothesized that users making reverse or intra-county trips would not be motivated to participate in value pricing in the same way that users making peak-direction trips are motivated and that any gender difference in tollway use could potentially be obscured if the study population is not strictly defined. For this reason, it is preferable to focus on the subset of respondents classified as peak-direction users.

Table 8.1 Transponder Ownership, All vs. Peak-Direction Users

	All Users (N = 1489)			Peak-Direction Users (N = 939)		
	Men	Women	Both	Men	Women	Both
Yes	51.2%	55.3%	52.6%	54.0%	64.8%	57.5%
No or Refused	48.8%	44.7%	47.4%	46.0%	35.2%	42.5%
TOTAL	100%	100%	100%	100%	100%	100%

³ A statistical comparison of these shares based on *weighted* observations appears later in Table 8.17 on page 91.

A third important difference between the current analysis and the analysis performed by Cal Poly is the condition of maintaining separate analyses for men and women. Table 8.2 shows the mode split reported for the most recent Monday through Thursday trips by 632 male and 307 female peak-direction respondents ($N = 939$). As shown in the left half of Table 8.2, which is based on unweighted observations, the proportion of men who traveled solo (76.9%) is greater than the proportion of women who traveled solo (63.2%). When men and women are combined, as in the roadside observations and descriptive statistics reported in the Cal Poly study, these differences are obscured. The weighted observations in the right half of the table show a similar difference between men and women, with 82.2% of men versus 63.8% of women choosing solo travel. The weighted shares in the right half of the table are adjusted for observed mode-time shares and reflect the condition of unequal sampling rates as shown in Table 7.5. Unless otherwise specified, weighted observations are used in the statistical tests that follow. In general, the expansion factors have a negligible effect of the conclusions drawn from the analysis. In cases where this is not true the effect is explicitly acknowledged.

Table 8.2 Unweighted vs. Weighted Mode Shares, Men vs. Women

	Unweighted			Weighted		
	Men	Women	Both	Men	Women	Both
Solo	76.9%	63.2%	72.4%	82.2%	63.8%	76.2%
Rideshare	23.1%	36.8%	27.6%	17.8%	36.2%	23.8%
TOTAL	100%	100%	100%	100%	100%	100%

Cross-Tabulation Methodology

The methodology employed here tests independence for bivariate count data arranged in two-way cross tabulations. These tables are sometimes called *contingency tables* because the alternative hypothesis in the test is that the variables are dependent (i.e., that

there is a contingency between the variables) (47). Two categorical variables that have been categorized in a contingency table with r rows and c columns are *independent* if the probability that a measurement is classified into a given cell of the table is equal to the probability of being classified into that row times the probability of being classified into that column. This must be true for all cells of the table.

The chi-square test of significance is a useful tool for determining whether it is worth the researcher's effort to interpret a contingency table. A statistically significant test result means that the cells of a contingency table should be interpreted for a potentially important association between the categorical variables. A non significant test result means that chance could explain the observed differences in the cells and therefore an interpretation of the cell frequencies is not useful (50). The chi-square statistic is used to test the null hypothesis (H_0) that two categorical variables, i and j , are independent.

The alternative hypothesis (H_a) is that the two variables are dependent. The test statistic is

$$\chi^2 = \sum_{i,j} \left[\frac{(n_{ij} - E_{ij})^2}{E_{ij}} \right] \quad (8.1)$$

where

n_{ij} = the number of observations in the cell for the i th row and j th column of the table (the i, j cell), and

E_{ij} = the expected number observations in the i, j cell under H_0 , which is taken to

$$\text{be: } E_{ij} = \frac{(\text{row}, i, \text{total}) * (\text{column}, j, \text{total})}{n}.$$

In this chi-square test, H_0 is rejected if χ^2 exceeds χ_c^2 , the tabulated critical value for significance level α and degrees of freedom, $df = (r - 1)(c - 1)$. Rather than running the test with a preset value of α , it is often preferable to report the probability of a Type I error (i.e., rejecting H_0 when H_0 is true) given df and χ^2 . This probability P determines the weight of the evidence for rejecting H_0 and is referred to as the *observed or attained level of significance*, or simply the P-value. A P-value equal to 0.025 ($P = 0.025$) means that if a sample is drawn 40 times⁴ and the chi-square test is performed with each sample, then approximately one chi-square test will be incorrect (47, p. 217). In other words, $P = 0.025$ indicates that H_0 can be rejected when the chosen significance level for the hypothesis test is greater than 0.025 (i.e., when $\alpha > 0.025$).

It is generally agreed that for 2 x 2 contingency tables and cases where the expected frequency is small (i.e., $5 \leq E_{ij} < 10$), the chi-square test tends to spot differences where none really exist (51, p. 362–363). Where appropriate to counter this tendency, Yates' *correction for continuity* is applied and explicitly noted. From each difference in the numerator of Equation 8.1, Yates' correction deducts 0.5 before squaring. The correction generates a smaller χ^2 value with a correspondingly larger P-value and is recommended for 2 x 2 contingency tables and small sample sizes (51). With or without Yates' correction, the chi-square test is *not appropriate* for tables larger than 2 x 2 when any E_{ij} is less than 1 or more than 20% of the cells have E_{ij} less than 5.

User Attributes

One set of inputs for estimating a discrete choice model for travel behavior is the user attributes (e.g., gender, income, household type, etc.). Tabulating these attributes is the usual first step toward understanding the study population. Given that numerous other

⁴ $1/P = 1/0.025 = 40$

researchers have observed differences between men and women in the usage of ridesharing and tollways, it is not unlikely that this study will find differences between men and women in choice set formation and choice behavior. The goal of this stage of the preliminary analysis is to find out if men and women are otherwise similar (i.e., if men and women have similar socioeconomic attributes).

As shown in Table 8.3, 45.7% of women and 54.4% of men reported that they are age 40 – 59 years. The share of commuters who reported that they are age 20 – 39 years is greater among women (43.3%) than among men (36.1%, $P = 0.099$). If it is true that there are more commuters age 20 – 39 years among women⁵, this may explain why, as shown in Table 8.4, the share of commuters who reported that they have a household income less than \$40,000 is larger among women (13.6%) than among men (9.1%, $P = 0.024$). Also as shown in Table 8.5, the share of commuters who report that they have children at home is smaller among women (52.7%) than among men (60.7%, Yates' $P = 0.034$).

Table 8.3 Men vs. Women, Age

$\chi^2 = 6.28, P = 0.099$	Women	Men
Age 20 – 39	43.3%	36.1%
Age 40 – 59	45.7%	54.4%
Age ≥ 60	8.7%	7.5%
Decline	2.3%	2.0%
TOTAL	100%	100%

⁵ Given that some commuters declined to report their age, the true age group percentages cannot be confirmed.

Table 8.4 Men vs. Women, 1998 Annual Household Income

$\chi^2 = 9.44, P = 0.024$	Women	Men
Income < \$40K	13.6%	9.1%
Income \$40 – \$100K	50.9%	56.4%
Income > \$100K	17.4%	21.0%
Decline	18.1%	13.5%
TOTAL	100%	100%

Table 8.5 Men vs. Women, Household Structure

Yates' $\chi^2 = 5.20, P = 0.023$	Women	Men
No HH Child	47.3%	39.3%
Yes HH Child	52.7%	60.7%
TOTAL	100%	100%

Table 8.6 shows the education distribution, where (25.8% + 11.2% =) 37.0% of women and (28.6% + 9.8% =) 38.4% of men report that they have a bachelor's degree or higher. As shown in the two tables that follow (Table 8.7 and Table 8.8), there is a larger share of men reporting full-time employment (91.3%) than women reporting full-time employment (79.4%, $P < 0.001$)⁶, yet the proportion of commuters who report professional or managerial occupations is about the same for the two groups (43.2% of men and 45.1% of women, $P = 0.615$).

⁶ At least 20% of the cells in the 4 x 2 employment contingency table have $E_{ij} < 5$, making it not appropriate for the chi-square test. The reported test results are for a modified 3 x 2 employment contingency table, which excludes persons who declined to report their employment status.

Table 8.6 Women vs. Men, Education

$\chi^2 = 4.39, P = 0.356$	Women	Men
High School or Less	17.4%	21.6%
Some College / Training	43.3%	38.0%
Bachelor's Degree	25.8%	28.6%
Graduate Work	11.2%	9.8%
Decline	2.3%	2.0%
TOTAL	100%	100%

Table 8.7 Women vs. Men, Employment

$\chi^2 = 31.8, P < 0.001$	Women	Men
Full Time	79.4%	91.3%
Part Time	8.2%	2.3%
Other	11.2%	6.2%
Decline	1.3%	0.2%
TOTAL	100%	100%

Table 8.8 Women vs. Men, Occupation

$\chi^2 = 0.97, P = 0.615$	Women	Men
Professional / Manager	45.2%	43.2%
Other	51.4%	54.2%
Decline	3.4%	2.6%
TOTAL	100%	100%

Perhaps the most noteworthy difference in the attributes of men and women is that women are more likely than men to not be working full time and thus may have more flexibility in their travel schedules. In terms of choice set formation, this suggests that women are more likely than men to have choice sets that include shoulder period travel.

Travel Choices

In addition to user attributes, the estimation of a discrete choice model also requires knowledge of the chosen alternatives. Tabulating the choice shares for the pooled data is an appropriate first step toward understanding the choice behavior of the study population.⁷ The primary goal for this stage of the preliminary analysis is to examine choice combinations such as route choice given mode, and find the answers to questions such as ‘Does route choice depend on mode choice?’

Before moving forward to investigate the choice shares for the most recent trips, it is useful to understand the nature of the trips. When asked about their most recent study period trip, 84.5% of women and 88.7% of men described a home-to-work or work-to-home trip (Yates’ $P = 0.082$), as shown in Table 8.9. Table 8.10, shows the distribution of peak trip times for solo travel along path that includes the SR-91 free lanes. As shown in Table 8.10 ($15.4\% + 20.1\% + 12.3\% =$) 47.8% of women versus ($19.7\% + 24.0\% + 16.3\% =$) 60.0% of men face a trip time of at least 55 minutes if they were to travel solo in the peak and not on a tollway ($P = 0.006$). Based on this, it appears that the characteristics of trips made by women are different than the characteristics of trips made by men. The observation that women are more likely than men to be making a non work trip suggests that women may be more likely than men to have formed more diverse choice sets that include ridesharing and shoulder period travel.

⁷ Previously in Section 7, the mode, route, and time choice shares were separately tabulated for each subsample.

Table 8.9 Women vs. Men, Trip Purpose

Yates' $\chi^2 = 3.03, P = 0.082$	Women	Men
Work Trip	84.5%	88.7%
Other Trip	15.5%	11.3%
TOTAL	100%	100%

Table 8.10 Women vs. Men, Trip Time

$\chi^2 = 16.20, P = 0.006$	Women	Men
< 35 minutes	10.8%	9.0%
35 – 44 minutes	19.3%	11.4%
45 – 54 minutes	22.2%	19.6%
55 – 64 minutes	15.4%	19.7%
65 – 79 minutes	20.1%	24.0%
≥ 80 minutes	12.3%	16.3%
TOTAL	100%	100%

The next two tables compare mode choice for work and non work trips. Table 8.11 shows that for women, 67.5% work trips are solo, whereas only 43.2% of non work trips are solo (Yates' $P = 0.002$). For men, the difference in mode choice between work and non work trips is not significant at the 10% level (Yates' $P = 0.199$). This can be seen in Table 8.12, where for men the proportions of solo work and non work trips are 82.9% and 76.0%, respectively. It also appears that regardless of the type of trip, women are more likely than men to travel with others. In terms of work trips, 32.5% of women

shared a ride versus 17.1% of men. For other trips, 56.8% of women shared a ride versus 24.0% of men.

Table 8.11 Women, Trip Purpose and Mode Choice

Yates' $\chi^2 = 9.34$, P = 0.002	Work Trip	Other Trip
Solo	67.5%	43.2%
Rideshare	32.5%	56.8%
TOTAL	100%	100%

Table 8.12 Men, Trip Purpose and Mode Choice

Yates' $\chi^2 = 1.65$, P = 0.199	Work Trip	Other Trip
Solo	82.9%	76.0%
Rideshare	17.1%	24.0%
TOTAL	100%	100%

Table 8.13 and Table 8.14 compare route choice for solo and rideshare users. Table 8.13 shows that for women the route shares for solo and rideshare are about the same (45.3% solo on tollway and 41.0% rideshare on tollway; Yates' P = 0.532). For men, the route shares for solo and rideshare are significantly different at the 10% level (27.6% solo on tollway versus 43.6% rideshare on tollway; Yates' P = 0.001). This suggests that route choice is associated with mode for men but not for women. Sullivan pools men and women together and concludes that HOV commuters are more likely than SOV commuters to choose the SR-91 tollway (44). Based on the gender-specific analysis given here, it appears that this is true for men but not women. This explains the

conclusion in the Cal Poly study that differences between men and women in route choice are significant only among solo drivers (45, p. 92).

Table 8.13 Women: Mode and Route Choice

Yates' $\chi^2 = 0.39, P = 0.532$	Solo	Rideshare
Tollway	45.3%	41.0%
Free	54.7%	59.0%
TOTAL	100%	100%

Table 8.14 Men: Mode and Route Choice

Yates' $\chi^2 = 10.34, P = 0.001$	Solo	Rideshare
Tollway	27.6%	43.6%
Free	72.4%	56.4%
TOTAL	100%	100%

The next two tables compare route choice for peak versus shoulder period travel. Table 8.15 shows that for women the route shares for peak and shoulder are essentially equal (43.7% of peak trips use tollway and 43.9% of shoulder trips use tollway; Yates' $P = 0.916$). For men the route shares are significantly different at the 10% level (33.5% of peak trips use tollway and 20.8% of shoulder trips use tollway; Yates' $P = 0.004$), as shown in Table 8.16. This suggests that time choice is associated with route choice only for men, and that women may be more likely than men to combine shoulder and tollway travel, perhaps because women are more likely than men to value safety and comfort attributes that might be associated with tollway travel.

Table 8.15 Women, Time and Route Choice

Yates' $\chi^2 = 0.001, P = 0.916$	Peak	Shoulder
Tollway	43.7%	43.9%
Free	56.3%	56.1%
TOTAL	100%	100%

Table 8.16 Men, Time and Route Choice

Yates' $\chi^2 = 8.17, P = 0.004$	Peak	Shoulder
Tollway	33.5%	20.8%
Free	66.5%	79.2%
TOTAL	100%	100%

Transponder Ownership and Use

Perhaps the most noteworthy difference between men and women is that 64.4% of women versus 52.9% of men report that they own a transponder, and this difference is significant at the 10% level ($P = 0.001$). This finding contradicts the Cal Poly report, which states that transponder ownership differences between men and women are not significant at the 10% level, Where 55% of women versus 50% of men in the sample report that they own a transponder (45, p. 113). By failing to weed out persons reporting reverse and intra-county trips, the Cal Poly study understates the significance of the difference between men and women regarding transponder ownership among peak-

direction users. The effect of reducing the sample to peak-direction users was originally illustrated using the unweighted observations in Table 8.1 on page 79.⁸

Table 8.17 Women vs. Men, Transponder Ownership

Yates' $\chi^2 = 10.76, P = 0.001$	Women	Men
Yes Transponder	64.4%	52.9%
No Transponder or Refused	35.6%	47.1%
TOTAL	100%	100%

Prior studies have shown that people use tollways with varying frequency (42,48), and it is widely agreed that the choice to acquire a transponder is not an indicator of a person's propensity for tollway travel (40,41). Table 8.18 compares transponder-owning men and transponder-owning women with respect to the proportion who actually chose tollway for the most recent trip. This is an analysis of conditional choice, route choice given that the decision maker owns a transponder. As shown, 63.0% of transponder-owning women chose tollway over free compared to 49.7% of transponder-owning men (Yates' $P = 0.004$).⁹ Not only are women more likely than men to own a transponder, they are also more likely to use the transponder they own to access tollways. Similar findings have been published elsewhere, yet the reasons for the gender difference are largely unknown. If this dissertation should find that different choice set groups have different

⁸ Due to differences in the way persons who refused to say whether or not they owned a transponder are handled, the unweighted proportions in Table 8.1 correspond to the percentages from the cited Cal Poly study within 1 percentage point.

⁹ Additional hypothesis testing not tabulated here finds that transponder-owning commuters are just as likely to choose tollway over free for non work trips as for work trips (Yates' $P > 0.999$ for women, Yates' $P = 0.664$ for men).

preferences for value pricing, it may be important to explore gender differences in choice set formation.

**Table 8.18 Transponder-Owning Men vs. Women,
Route Choice**

Yates' $\chi^2 = 8.32, P = 0.004$	Women	Men
Tollway	63.0%	49.7%
Free	37.0%	50.3%
TOTAL	100%	100%

Additional tests were conducted to identify other user attributes that might be useful in predicting tollway usage among transponder owners. Table 8.19 for women and Table 8.20 for men are specific to transponder owners and address questions such as ‘Among commuters who own a transponder, are persons with higher household incomes more likely to actually choose tollway travel over free travel than persons with lower household incomes?’

As shown in the first row of Table 8.19, 64.2% of Yes Degree women who own a transponder used a tollway for the most recent trip versus 60.9% of No Degree women who own a transponder. Yates’ chi-square statistic for this cross tabulation is given as 0.10 with $P = 0.747$, which suggests that it may not be worthwhile to further explore the relationship among transponder-owning women between education and tollway travel. Based on the other test results given in Table 8.19, it appears that one transponder-owning female is about as likely as another to choose tollway travel over free travel (Yates’ $P > 0.250$ for all tests). The suggestion in the last two rows for women that route choice may be independent of mode and time was previously demonstrated in Table 8.13 and Table 8.15 prior to specifically targeting transponder owners.

Table 8.19 Women, Proportion Choosing Tollway over Free Travel

	Proportion of Yes [Attribute] Women Who own Transponder and Used Tollway	Proportion of No [Attribute] Women Who own Transponder and Used Tollway	Yates' χ^2 =	P =
Degree	64.2%	60.9%	0.10	0.747
Professional	65.5%	60.7%	0.29	0.588
Income > \$80K	64.6%	60.0%	0.09	0.760
HH Child	59.2%	67.9%	1.26	0.262
Accent	56.8%	63.8%	0.16	0.689
Age (30 – 49)	59.0%	68.2%	1.28	0.258
Work Trip	62.8%	65.1%	< 0.01	>0.999
Rideshare	63.5%	61.6%	0.01	0.933
Shoulder	67.8%	61.8%	0.29	0.588

The same series of tests is shown for men in Table 8.20. At the 10% level, it does not appear that any of the user attributes listed in the first six rows of Table 8.20 are associated with route choice. Prior to specifically targeting transponder owners, a strong association between route and mode choice and route and time choice was previously demonstrated in Table 8.14 and Table 8.16, respectively. Here, in Table 8.20, mode but not time is shown to be associated with route choice for transponder-owning men at the 10% level ($P = 0.038$).

Table 8.20 Men, Proportion Choosing Tollway Travel over Free Travel

	Proportion of Yes [Attribute] Men Who own Transponder and Used Tollway	Proportion of No [Attribute] Men Who own Transponder and Used Tollway	Yates' χ^2 =	P =
Degree	46.5%	53.0%	1.14	0.286
Professional	51.8%	46.4%	0.73	0.393
Income > \$80K	56.9%	46.8%	2.29	0.130
HH Child	51.6%	47.6%	0.28	0.616
Accent	46.4%	50.15%	0.05	0.825
Age (30 – 49)	53.3%	43.5%	2.52	0.112
Work Trip	49.3%	55.7%	0.19	0.664
Rideshare	61.4%	46.7%	4.27	0.039
Shoulder	40.5%	52.2%	2.52	0.113

In terms of describing the route choice behavior of transponder owners, it appears that gender is the only user attribute that is associated with tollway usage at the 10% level. Again, it appears that the effect that mode or time of travel has on the decision to use tollways is potentially different for men and women, yet there is no apparent explanation for this.

Conclusion

It should be noted that associations between specific user attributes and choice behaviors identified here are of a preliminary nature, suitable only for guiding model development.

This is because the preceding analysis does not account for interactions among the independent variables. The model development task in Section 13 delves into these issues further by testing for specific interactions.

Even without the benefit of accounting for potential correlations, the general impression at this stage is not dissimilar to what other model developers have concluded; the array of statistically significant associations between user attributes and choice behavior is rather underwhelming (see for example, 42 and 40) and suggests variability in choice behavior due to unobserved heterogeneity. Motivated by this problem, this dissertation examines the potential to observe the considered choice set and test it as a potential indicator of choice behavior in value pricing. Toward this end, the next section introduces the procedure for estimating user choice sets.

9 CHOICE SET FORMATION

Choice set formation is the process of establishing the set of feasible alternatives available to a decision maker. Various researchers describe choice set formation as a constraint-driven process, whereby a variety of factors, including those of a psychological nature, can establish the infeasibility of an alternative for an individual decision maker (52). This study assumes, for example, that the potential for some users to be constrained against ridesharing because of psychological factors related to privacy or unbounded¹ movement is non trivial and should not be overlooked in a model of value pricing. This research proposes to separate decision makers who do not consider ridesharing to be feasible and evaluate the extent to which these users make different trade-offs in value pricing compared to others. A related objective is to separate decision makers who do not consider shoulder period travel as feasible, perhaps because they cannot manage an early a.m. departure and their employer does not permit a late a.m. arrival.

Much of the discrete choice literature assumes that choice set can be predicted deterministically based on observable constraints. Applications of this are typically limited to cases of removing the drive alone option from the choice set for persons who do not possess a driver's license or removing the transit option when the walking distance to the transit stop exceeds a pre defined value. In contrast to these readily identifiable constraints, the current study assumes an array of lifestyle and psychological constraints that may potentially cause a person to perceive ridesharing and / or shoulder period travel as infeasible alternatives. Accounting for these constraints (e.g., needs for privacy or spontaneity in departure time) is much more difficult. Rather than seek to explicitly identify and measure the constraints, this study takes a markedly different approach, which is to estimate a person's choice set based on their revealed history of actual choices.

¹ Unbounded movement, meaning freedom to depart at any time and travel to any destination.

The technique used here is similar to the method of empirical choice set formation proposed by O'Neil and Nelson (2) for a mode choice model for the Baltimore area. Empirical choice set formation is uniquely responsive to potentially unidentifiable circumstances and attitudes that may affect perceptions regarding mode and time feasibility. The procedure virtually guarantees that ridesharing will be excluded from the choice set when there is a zero probability for choosing it; likewise for shoulder period travel. For an unknown number of decision makers, the procedure necessarily *underestimates* the true choice set by also excluding these alternatives when the choice probabilities are non-zero. The potential for underestimating the choice set is assessed in Table 9.2 on page 108 and is found to be acceptable in the context of the study objectives.

An example of empirical choice set formation is given in Haselkorn et al. (53). Researchers at the University of Washington surveyed Seattle area freeway commuters and discovered four subgroups in terms of willingness to change mode, route, or departure time in response to motorist information. The current study *prescribes* four subgroups in terms of whether or not the pre-trip choice probability for the rideshare mode and the shoulder time is greater than zero and then tests for variations in choice behavior for value pricing.

Choice Set Theory

Like most studies regarding the demand for value pricing, this one is concerned with individual choice behavior. Any choice that an individual makes can be described as being made from a nonempty set of alternatives denoted by $j = 1, \dots, J$. The marketplace² determines what is generally referred to as the *universal set* of alternatives M . This study takes the view that a single decision maker n considers a subset of the

² Meaning the environment in which the population of decision makers operates.

universal set known as the *choice set* or the *considered set* $C_n(I)$. This implies a two-stage choice paradigm where the first stage is the process of defining the subset of objectively available alternatives that the decision maker actually considers for choice (29). It has been suggested that C_n depends on n 's specific environment and reflects a variety of constraints (22, p. 34) including

- Physical availability (e.g., j may not service n 's origin or destination),
- Monetary resources (e.g., j may be unaffordable given n 's household income),
- Time availability (e.g., j may not service n 's designated arrival time),
- Informational constraints (e.g., n may not know about the service j provides), and even
- Psychological / social constraints (e.g., regardless of the service j provides, in terms of infrastructure, travel time, and cost, n may fail to consider j due to n 's perception of some other attribute(s) of j)³

Choice Set Generation Models – State of the Practice

Given that the specific alternatives composing an individual's choice set cannot be observed and given the uncertainty of potential constraints, the analyst has a number of options, including the following:

1. Ignore the problem and assume that each individual chooses from the same universal choice set.
2. Introduce availability and/or attitudinal variables in choice model disutility specifications.

³ An example is a commuter who will not consider the travel time and cost benefits of using the carpool mode because he perceives ridesharing as a threat to his personal privacy.

3. Formulate individual choice sets deterministically based only on observable constraints that can be treated with certainty.
4. Formulate choice sets probabilistically based on random constraints.
5. Formulate individual choice sets deterministically based on user-supplied information on alternative availability.

Each of these methods is discussed below. See Swait and Ben-Akiva (26) for a complete review of choice set formation modeling.

Assume Everyone Chooses from the Universal Choice Set

In many practical cases, given the wide array of specific environments that individuals operate within, the assumption that everyone chooses from the same universal choice set is unrealistic. The assumption of the universal choice set can be especially problematic in the type of multidimensional choice situation that is characteristic of value pricing. Any constraint that causes a decision maker to not consider shoulder period, travel for example, effectively eliminates multiple mode-route-time combinations from the choice set. When the universal choice set is assumed for every decision maker there is the potential that the model parameters may be driven not only by variations among individuals in their preferences but also by the *unaccounted* for variations among individuals in their choice sets (54).

Introduce Availability or Attitudinal Variables

The approach of simulating the feasibility of an alternative implicitly in the choice model of the same alternative by introducing an availability attribute such as flexible work hours is used in some of the route-time choice models in the value pricing literature (40,41). This treatment is convenient for the analyst because it does not require explicit information about individual choice sets. However, the treatment tends to confuse disutility attributes with availability attributes (i.e., feasibility attributes) and can lead to mis-specification errors if the same attribute plays a dual role (26,28).

Incorporating attitudinal factors into choice functions opens the analysis to different types of constraints but also has the problem of confusing disutility attributes with availability attributes. These efforts are challenged by conflicting reports on the extent to which attitudinal variables explain travel behavior and improve travel models. Tardiff (55) reports that the effect of behavior on attitude seems to be more important than the reciprocal interaction. On the other hand, Recker and Golob (56) recommend including attitudinal variables in disaggregate models of mode choice when separate models are developed for different market segments.

Deterministic Choice Set Formation

Swait and Ben-Akiva (26) point out that a given constraint “can be thought of as deterministic or probabilistic depending on the degree of confidence the [analyst] places on the information at hand.” *Some* reliable information is easily collected and it is therefore not uncommon for deterministic choice sets to be sensitive to constraints such as not being in possession of a driver’s license, having no access to a vehicle, or traveling between locations not serviced by transit. Constraints that pertain to a person’s lifestyle, knowledge, or beliefs are much more difficult and costly to assess and are seldom included in deterministic choice set formation modeling. One example is a study of trip-chaining behavior by Recker et al. (57), which allows for combinations of household and infrastructure constraints to restrict the set of feasible activity patterns.

Probabilistic Choice Set Formation

Probabilistic choice set models are theoretically appealing because they explicitly represent uncertain knowledge of the choice set. These models are based on the following conditional probability expression suggested by Manski (29) for the probability of individual n choosing alternative j :

$$P_n(j) = \sum_{M_r} P_n(j|M_r) P_n(M_r) \quad (9.1)$$

where M , the universal choice set, is subdivided into R distinct and non empty subsets, denoted by M_r , $r = 1, \dots, R$.

$P_n(j)$ = probability of individual n choosing alternative j ($j \in M$),

$P_n(M_r)$ = probability that individual n 's choice set is M_r ($C_n = M_r$), and

$P(j|M_r)$ = probability of individual n choosing alternative j given choice set M_r .

Probabilistic choice set models are rarely used because they are computationally burdensome as the set of all possible non empty choice sets increases exponentially with the number of alternatives. In favoring the notion of random constraints in forming choice sets, Swait and Ben-Akiva (26) propose to reduce the computational difficulties by restricting the choice set possibilities and also by incorporating deterministic constraints.

Forming Choice Sets Based on User-Supplied Information

The alternative of formulating choice sets deterministically based on user-supplied information regarding alternative feasibility is a fairly straightforward approach. The problem with stated availability data is that the set of alternatives a person says he views as feasible may be larger than the true set. Responses to questions such as "Are you able / willing to carpool?" or a series of hypothetical choice scenarios are usually inadequate for identifying the considered choice set because respondents tend to under estimate the influence of psychological constraints or because they want to view themselves or be viewed by others as a person who is willing to consider a wider set of alternatives than is true. This type of approach is useful as a descriptive model, but is limited in terms of predicting or forecasting travel behavior.

Study Approach for Choice Set Formation

The current study estimates the choice set deterministically based on a person's revealed history of choice behavior, effectively eliminating all zero-probability alternatives. In the context of a *typical* half-day O-D survey, where the revealed behavior generally includes only the choice on which the model is calibrated, the usual approach is to arrive at the unknown considered set by adopting one of the five approaches listed previously. The travel survey featured in this study was uniquely crafted to observe a larger set of behaviors over time. Specifically, survey respondents were asked to describe multiple trips, compare travel today with travel 2 years ago, and also identify the actions they have taken to avoid peak period congestion, such as leaving early or late to avoid the peak or carpooling to gain access to HOV lanes. In the context of the choice situation depicted in this study, the set of behaviors revealed in the responses to these questions should be adequate for an empirical estimation of the considered choice set. The supporting assumptions and the estimation procedure are given below.

Study Approach – Assumptions

It is assumed that individual choice behavior involves making a selection conditioned on the considered set $(j | C_n)$, where C_n is the set of alternatives identified by the decision maker to be feasible at the time of the decision. The following premise is offered for a given set of activities: when the choice set is stable over time and variations in choice behavior are not uncommon, then multiple observations of revealed choice provide the analyst with a strong basis for estimating the considered set.

One reason that the premise is a likely one is that the decision process for peak period travel typically repeats multiple times per week, which gives the analyst ample opportunity to observe the usual variations in choice behavior. The choice for a particular choice dimension like mode may depend on the choice for another dimension like time, which may change exogenously from one instance of the decision to the next. Even when C_n is unchanging, the revealed choice $(j | C_n)$ may change from one time of

the decision to the next. For example, a commuter who shares a ride to work on Monday may choose a different mode on Tuesday should the departure time be different and exogenously set so as to cause the rideshare alternative to offer lesser utility (i.e., greater disutility) than the competing mode.

This study assumes that each revealed choice in a person's recent history of peak period decision making is an element of the considered set for any peak period trip. This is not entirely realistic because the considered set may change over time. Given that C_n depends on n 's specific environment, which may change from one time of the decision to the next, C_n may also change from one time of the decision to the next. Consider a commuter who shared a ride to work on Monday because he was captive to the rideshare mode, perhaps due to needed car repairs or family responsibilities for transporting a child. Should the prevailing circumstances for Tuesday be different, it is possible that this commuter may consider ridesharing to be an infeasible alternative, regardless of the relative disutility.

It is hypothesized that for peak trips, choice situations like the one described immediately above occur infrequently and it is uncommon that in surveying a commuter about his choice for the most recent peak period trip that an analyst would identify a revealed choice that is not a considered choice for another instance of the decision. Thus, it is assumed that the choice set is generally stable over time and that most of the observed variations in choice behavior are conditioned on other choice dimensions, which may be set exogenous to the decision process and are not a consequence of changing feasibility criteria.

Study Approach – Specification

The universal choice set M is subdivided into R unique and nonempty subsets, denoted by M_r , $r = 1, \dots, R$, where one of the subsets is the universal choice set, M . For this study, the universal set includes each of the eight multidimensional alternatives listed in

Table 9.1 below. Each of the eight alternatives is a multidimensional mode-time-route combination wherein each of the three choice dimensions is given a binary representation. In this table, a label is given to each mode-time-route combination. Herein, the solo-peak-free alternative found in the first row is referred to as the Endure alternative. The other alternatives are all named for a different method of reducing the extent to which a commuter “endures congested travel conditions.” For example, the rideshare-peak-free alternative is named for the Carpool method of bypassing some peak period congestion, whereas the solo-shoulder-free alternative is named for the time Shift method of avoiding some of the worst congestion. Based on the assigned names, the universal choice set M is defined as $= \{\text{Endure, Carpool, Pay, Carpool \& Pay, Shift, Shift \& Carpool, Shift \& Pay, Shift \& Carpool \& Pay}\}$.

Table 9.1 Eight Multidimensional Alternatives

$j =$	Travel Choice	Mode	Time	Route
1	Endure	Solo	Peak	Free
2	Carpool	Rideshare	Peak	Free
3	Pay	Solo	Peak	Tollway
4	Carpool & Pay	Rideshare	Peak	Tollway
5	Shift	Solo	Shoulder	Free
6	Shift & Carpool	Rideshare	Shoulder	Free
7	Shift & Pay	Solo	Shoulder	Tollway
8	Shift & Carpool & Pay	Rideshare	Shoulder	Tollway

As specified, an individual who does not consider ridesharing necessarily chooses from the four-element subset $\{\text{Endure, Shift, Pay, Shift \& Pay}\}$ because the other four alternatives in Table 9.1 have mode = rideshare and are effectively not available to the

decision maker. Likewise, an individual who fails to consider shoulder period travel chooses from the four-element subset $\{\text{Endure}, \text{Carpool}, \text{Pay}, \text{Carpool \& Pay}\}$, and an individual who considers neither ridesharing nor shoulder period travel is limited to the two-element subset $\{\text{Endure}, \text{Pay}\}$. In total, there are four possible choice sets M_1 , M_2 , M_3 , and M_4 , where:

$$M_1 = \{\text{Endure}, \text{Pay}\}$$

$$M_2 = \{\text{Endure}, \text{Carpool}, \text{Pay}, \text{Carpool \& Pay}\}$$

$$M_3 = \{\text{Endure}, \text{Shift}, \text{Pay}, \text{Shift \& Pay}\}$$

$$M_4 = M = \{\text{Endure}, \text{Carpool}, \text{Pay}, \dots, \text{Shift \& Carpool \& Pay}\}$$

C_n is the choice set of a single individual, which is equal to one of the M_r 's.

Commuters with like choice sets are grouped into four segments, which are labeled as follows: Endurers ($C_n = M_1$), Carpoolers ($C_n = M_2$), Shifters ($C_n = M_3$), and Avoiders ($C_n = M_4$). Endurers have the most limited choice set in that it only includes the Endure ($j = 1$) and Pay ($j = 3$) alternatives. Shifters and Carpoolers have the same size choice set with four alternatives. Shifters choose between Endure and Pay plus two alternatives involving shoulder period travel ($j = 5$ and $j = 7$). Carpoolers choose between Endure and Pay plus two alternatives involving ridesharing ($j = 2$ and $j = 4$). Avoiders are the least limited and choose from the universal set of eight alternatives ($j = 1, \dots, 8$).

Whereas additional subsets of M can be formulated, restricting the analysis to four subsets, $G = \{M_1, M_2, M_3, M_4\}$, is sufficient for the purposes of this study. The approach of defining 8 or more subsets of M , including permutations with and without Endure and Pay, was proposed by this author in 2002 in a poster session at the 81st Annual Meeting of the Transportation Research Board. For the purpose of this

dissertation, the author makes no assumption regarding commuters who may consider tollway travel to be infeasible. As previously stated in Section 5, the primary motivation for this is to limit the number of choice sets that must be enumerated, so that the study sample is more efficiently utilized. Certainly, it is true that not every commuter owns a transponder; approximately 36% of women and 47% of men do not. Because an on-board transponder is a requirement only for the SR-91 tollway, and not the Eastern tollway, transponder ownership is not readily treated as a deterministic constraint.

The condition of being captive away from the Endure alternative is clearly relevant to a properly specified choice set. However, this dissertation is specifically concerned with the effects of failing to consider one or more of the “positive” alternatives to enduring congestion (e.g., ridesharing and shoulder period travel) on tollway participation. The condition that a commuter may be captive to ridesharing or shoulder period travel is of some interest and may be worth exploring in future research.

Study Approach – Estimation

The objective of the choice set estimation is to identify, for each person in the sample, the particular subset of M that is his considered set ($C_n = M_r$). C_n is n 's true considered set for the choice situation. Let C'_n be decision maker n 's *estimated* choice set, and let C''_n be the set of mode and time choices revealed in response to questions regarding n 's history of study period travel in the SR-91 corridor. It is assumed that C''_n is a subset of C_n ($C''_n \subseteq C_n$). In this study, the estimated choice set (C'_n) is taken as the set of choices revealed in the survey responses ($C'_n = C''_n$).

The set of questions that provide information about a person's history of choice behavior for study period travel are spelled out in the next section, Section 10. Some of these questions asked about trips made two years ago. Specific to the full set of questions, the potential for error in choice set estimation is discussed in Section 10.

To illustrate a potential problem with this approach, consider individual n , who has a history of study period choices that includes instances of ridesharing but no instances of shoulder period travel (i.e., $C_n'' = M_2$). With this information, the individual is classified as a Carpooler, $C_n' = M_2$, but there is no guarantee that this individual has *actually* eliminated alternatives involving shoulder travel from his choice set because all that is known is that he hasn't previously *chosen* shoulder period travel. It is possible that there is no history of shoulder period travel not because it is excluded from the considered set, but because it offers low utility compared to other considered alternatives. If the true probability of choosing shoulder period travel is greater than zero, then individual n is actually an Avoider ($C_n = M_4$) and the estimated choice set is smaller than the true choice set ($C_n' = M_2 < C_n = M_4$).

The problem of not representing alternatives that people actually do consider ultimately makes it difficult in the model estimation to confirm real differences in behavior across subgroups from differences due to a potential bias resulting from the criteria used to define them. This is a general problem with defining constrained choice sets, and is not specific to this dissertation. For the particular method used here, there is the possibility that the people comprising the different segments are “self-selected” in such a way that persons with a low preference (but non-zero probability) for ridesharing are classified as Endurers or Shifters while persons with a low preference (but non-zero probability) for shoulder travel are classified as Endurers or Carpoolers.

For each choice set estimation, Table 9.2 identifies the various ways the choice set can be mis-specified. In this table, when the estimated choice set is equal to the true choice set ($C_n' = C_n$), then the estimation is labeled “CORRECT.” As shown in the third row, when the study method is used and individual n is identified as a Shifter ($C_n' = M_3$), only one type of “INCORRECT” classification is possible ($C_n' = M_3 < C_n = M_4$). This represents the condition where the individual is actually an Avoider, not a Shifter,

because he considers but has not previously chosen to rideshare. As shown by the “N / A” label (meaning not applicable), the other mis-specifications do not result. Because neither M_2 nor M_1 include alternatives with the shoulder time and shoulder period travel was observed in the revealed history of choice behavior, it is assumed that $C_n \neq M_2$ and $C_n \neq M_1$.

Table 9.2 Ways for the Choice Set Estimation to Mis-Specify the True Choice Set

		TRUE CHOICE SET			
		$C_n = M_3$	$C_n = M_2$	$C_n = M_1$	$C_n = M_4$
ESTIMATED CHOICE SET	$C'_n = M_1$ Endurer	INCORRECT $C'_n = M_1 < C_n = M_3$	INCORRECT $C'_n = M_2 < C_n = M_3$	CORRECT $C'_n = C_n$	INCORRECT $C'_n = M_1 < C_n = M_4$
	$C'_n = M_2$ Carpooler	N / A	CORRECT $C'_n = C_n$	N / A	INCORRECT $C'_n = M_2 < C_n = M_4$
	$C'_n = M_3$ Shifter	CORRECT $C'_n = C_n$	N / A	N / A	INCORRECT $C'_n = M_3 < C_n = M_4$
	$C'_n = M_4$ Avoider	N / A	N / A	N / A	CORRECT $C'_n = C_n$

As shown in Table 9.2, the Avoider estimation ($C'_n = M_4$) is the most certain (i.e., $C'_n = C_n$ for all Avoiders) and the Endurer estimation ($C'_n = M_1$) is the least certain (i.e., $C'_n = C_n$ for some but not all Endurers). In accordance with the study method, individual n is identified as an Endurer ($C'_n = M_1$) when there are no rideshare or shoulder travel observations in his revealed history of choices (i.e., when $C''_n = M_1$). The

first row of Table 9.2 identifies exactly three ways that the Endurer estimation can underestimate the true choice set. As there is no way of knowing the true choice set, the analyst can only speculate about the potential to mis classify the sampled individuals.

The benefit of the proposed choice set formation model is that it guarantees that any Shifter-specific analysis of tastes for value pricing will necessarily express the preferences of commuters who consider shoulder period travel as a viable option, be they true Shifters or true Avoiders. Similarly, any Carpooler-specific analysis will express the presumably distinct preferences of commuters who consider ridesharing to be a viable option, be they true Carpoolers or true Avoiders. As previously stated, there is a price to be paid for this. There is the problem of not representing alternatives that people actually do consider, and the potential for a self-selection bias if, for example, persons with low preferences for ridesharing are systematically assigned to the Endurer and Shifter segments instead of the Carpooler and Avoider segments. The premise of this research is that it is preferable to exclude considered alternatives than to include alternatives that are not considered. Further, it is hypothesized that the subset of alternatives a person actually considers for choice is an important explanatory variable when it comes to describing choice behavior for value pricing.

An alternate treatment would be a probabilistic approach that explicitly represents the uncertain choice sets within the constraints of the revealed choices. For a commuter classified as a Shifter with $C'_n = M_3$, the following restricted choice set probabilities would sum to 1: $0 \leq \Pr(C_n = M_3) \leq 1$, $\Pr(C_n = M_2) = 0$, $\Pr(C_n = M_1) = 0$, $0 \leq \Pr(C_n = M_4) \leq 1$. This choice set formation model resolves the problem of excluding unobserved choices, and is perhaps the next logical step for this line of research.

Conclusion

As described, the empirical choice set formation model is uniquely specified to eliminate from each user's choice set the alternatives with a zero choice probability. The preferred situation for applying this model is one where each sampled individual is studied for 1 year and submits a 1-week travel diary on a quarterly basis. This should be sufficient to capture for each individual the full array of alternatives used. Perhaps the *ideal* situation is an extended study of this type that begins when the study corridor contains only general-purpose lanes, continues after a carpool lane is added, and concludes after the carpool lane is converted into a HOT lane. It would be interesting, for example, to know if shoulder period travel dropped out of a person's choice set after the opening of the carpool lane or if ridesharing dropped out of a person's choice set following the HOT lane conversion. This type of study also has the advantage of permitting choice set estimation exogenous to the behavior of choosing value pricing (or not) given choice set.

In the context of the current study, neither the ideal nor the preferred implementation scheme is possible. Instead, the choice sets are estimated from responses to telephone survey questions, only one of which was specifically developed for the purpose of choice set estimation. For this author, the only opportunity to survey users about their history of travel behavior was a telephone survey planned in conjunction with a Caltrans-sponsored evaluation of the SR-91 tollway. While it was not the primary purpose of the survey to gather data for choice set estimation, this author did have the opportunity to incorporate questions about past behavior and was able to do so with the goals of this dissertation in mind. The questionnaire turned out to be unusually long⁴, and this opportunity was severely limited. Nonetheless, the available data set is believed to be adequate for the purposes of the current study. The individual survey items used for choice set estimation are presented in the next section along with a specific procedure for using the responses to these items to form choice sets.

⁴ It took some respondents 25 minutes to complete the telephone survey.

10 ESTIMATING THE CHOICE SETS

This section further develops the methodology for choice set formation by examining the specific elements of the survey instrument for revealed behaviors. Whereas the previous section described the model for estimating considered choice sets as a function of a actual choice behavior, the current section establishes the criteria for the analyst in terms of identifying choices based on responses to specific questions in the survey. In essence, this is the heuristic rule set for choice set formation.

Revealed Choice Defined

In order to use the survey data to estimate choice sets in accordance with the approach outlined in Section 9, the criteria for identifying a revealed choice must first be established.

Mode Choice

As previously stated, the mode choice dimension is a binary variable where one alternative is solo and the other alternative is rideshare. Rideshare is defined as two or more persons per vehicle. If a survey respondent reports that there was more than one person in the vehicle, the revealed mode choice is identified as rideshare. Even though vehicles with three or more occupants (HOV-3+) get a discount on the SR-91 tollway, this study does not distinguish between HOV-2 and HOV-3+ modes. For some users, this simplification will over-estimate the per-person cost of the Carpool & Pay and Shift & Carpool & Pay alternatives. The earlier discussion of mode choice beginning in Section 5 addresses this issue in detail and evaluates the implications.

The survey includes a question about usual travel behavior that does not explicitly inquire about the number of occupants yet can be used to infer mode choice. This is Question 148 in the survey instrument in Appendix A, which is reproduced later in this section. With respect to Question 148, the rideshare mode choice is indicated by the

reported use of carpool lanes. Throughout Southern California, carpool lanes are restricted to vehicles with two or more persons. It is assumed that solo drivers do not violate this restriction and that any reported use of a carpool lane is associated with the rideshare mode.

Time of Day Choice

The time choice dimension is a binary variable where one alternative is peak and the other is shoulder. Peak refers to a trip that *crosses the county line* during the middle of either the a.m. or p.m. period, when congestion is at its worst. As part of the travel time estimation work described in Section 6, the Cal Poly team used the network models to estimate for each respondent, the time of crossing the county line as a function of the reported origin, departure time, mode, and route. This time is important because for the SR-91 tollway, the amount of the toll depends not on the time of departure, but on the time that the vehicle arrives at the toll facility, which is located adjacent to the Orange and Riverside County line.

Peak travel refers to a trip that crosses the county line in the middle of either the a.m. or p.m. period when congestion is at its worst, and shoulder travel refers to a trip that crosses the county line before or after the middle period. Within the study period of 4:00 to 10:00 a.m. and 2:00 to 8:00 p.m., two peak and four shoulder periods are explicitly defined, as shown in Table 10.1. By inspection, a commuter estimated to have crossed the county line at 4:30 a.m. is treated as having traveled during a shoulder period, whereas a commuter estimated to have crossed the county line at 5:30 a.m. is treated as having traveled during a peak period.

Table 10.1 Peak and Shoulder Periods and Tolls

Time	Peak vs. Shoulder	SR-91 Tollway Toll 1999
Morning (a.m.)		
4:00 – 5:00 a.m.	Shoulder	\$1.65
5:00 – 6:00 a.m.	Peak	\$2.90
6:00 – 7:00 a.m.	Peak	\$3.00
7:00 – 8:00 a.m.	Peak	\$3.25
8:00 – 9:00 a.m.	Peak	\$2.90
9:00 – 10:00 a.m.	Shoulder	\$1.95
Afternoon (p.m.)		
2:00 – 3:00 p.m.	Shoulder	\$2.95
3:00 – 4:00 p.m.	Peak	\$3.20
4:00 – 5:00 p.m.	Peak	\$3.35
5:00 – 6:00 p.m.	Peak	\$3.35
6:00 – 7:00 p.m.	Peak	\$3.20
7:00 – 8:00 p.m.	Shoulder	\$2.25

There is an approximate and deliberate correspondence between the 1999 SR-91 toll schedule and the choice of boundaries between peak and shoulder period travel. For morning travel, peak tolls are set between \$2.90 and \$3.25 and shoulder tolls are as low as \$1.65. For evening travel, peak tolls are set between \$3.20 and \$3.35 and shoulder tolls are as low as \$2.25. By design of the boundaries between peak and shoulder travel, the only “within study period” opportunities to travel in the SR-91 tollway at a “substantial” savings over the maximum toll occur in shoulder periods. Assuming that roadway detector estimates are accurate and that travelers accurately estimate their time

savings, the choice to use the SR-91 tollway during a peak period is a choice to trade about \$3.00 per vehicle for up to 29 minutes of travel time savings (45, p. 48). The choice to use the SR-91 tollway during a shoulder period is a choice to trade about \$2.00 per vehicle for up to 5 minutes of travel time savings.

It should be noted that any other set of peak period boundaries that might be considered would have the effect of blurring the desired distinction between the solo-shoulder-free (Shift) and the solo-peak-tollway (Pay) alternatives. It is not unlikely that when choosing to not use the Endure alternative, some travelers perceive the Shift alternative as a substitute for Pay alternative, and vice versa. Any change to the boundaries that extends the shoulder periods would have the effect of increasing the travel time attribute of the Shift alternative relative to the travel time attribute of the Pay alternative.

The previously mentioned Question 148 is a multiple response question than can also be used to infer time choice. In the context of this question, shoulder period is indicated by travel reported to have taken place “early or late to avoid peak period congestion.” It is assumed that travelers who alter their schedules for the express purpose of avoiding recurrent congestion do so in order to capture the type of substantial travel time savings that can only be achieved by avoiding the middle of the a.m. or p.m. period. Accordingly, a person who reports that he departed early or late to avoid peak period congestion is treated as having a history of travel behavior that includes shoulder period travel.

It is apparent from the phrasing of the Question 148 that the analyst cannot be certain the reported behavior actually coincides with the time boundaries of shoulder period travel as defined in Table 10.1. The possibility remains that a person who reports departing early to avoid a.m. congestion may be someone who has no actual history of crossing the county line any earlier than 5:30 a.m. On the basis that a positive response indicates the individual has experience adjusting his departure time for the purpose of avoiding

congestion, it is not inappropriate to include shoulder period travel in specifying his considered choice set. In terms of the model estimation, the potential consequence for the Shifter segment of the population is to overestimate the probability of shoulder period travel.

Route Choice

Observations about route choice are not used to estimate the choice sets. As previously stated, the choice sets are structured so each potential choice set M_r , $r = 1, \dots, R$ includes alternatives involving tollway travel. While some travelers may face budgetary constraints that cause them to perceive tollway travel as an infeasible route alternative, this study makes no a priori assumptions regarding this. The procedure treats tollway travel as being feasible for all travelers and preferences for it are measured by the model estimation.

Criteria for using survey data to identify the route choice for the most recent Monday through Thursday trips are need for the model estimation. Route choice is a binary variable; the available alternatives are free and tollway. The SR-91 tollway and the Eastern tollway are the only tollways in the study corridor. Even though the SR-91 and Eastern tollways have different alignments and different operating characteristics, the

current model does not distinguish between them. This study takes the view that travelers perceive tollway travel as one of several available means for avoiding or bypassing congestion. In the SR-91 corridor, this particular means is available by way of a fixed price toll to access the Eastern tollway or by way of time-varying toll to access the SR-91 tollway. Thus, any route that coincides with either the Eastern tollway or the SR-91 tollway is classified as tollway, not free.

The implications on the choice model of a binary route choice specification are addressed in the earlier discussion of route choice beginning in Section 5. For most O-D pairs, the fixed toll on the Eastern tollway is greater than or equal to the time-varying toll on the SR-91 tollway, except during the 4:00 to 6:00 p.m. period when the toll on the Eastern is \$0.10 (3%) less than the toll on the SR-91 tollway, as shown in Table 10.2. For trips to the City of Orange and vicinity vehicles exit the Eastern tollway at Chapman and the toll is \$2.25, \$1.00 less than shown in Table 10.2. When the two tollways compete, it is assumed that the traveler chooses the one that gives the best value in terms of the amount of the toll, the travel time savings, and the individual's value of time. The analytical methods for handling these situations are given in the earlier discussion on aggregating network travel times and tolls (see Section 6).

Table 10.2 Time-of-Day Toll Comparisons

	SR-91 tollway	Eastern tollway ¹
Morning (a.m.)		
4:00 – 5:00 a.m.	\$1.65	\$3.25
5:00 – 6:00 a.m.	\$2.90	\$3.25
6:00 – 7:00 a.m.	\$3.00	\$3.25
7:00 – 8:00 a.m.	\$3.25	\$3.25
8:00 – 9:00 a.m.	\$2.90	\$3.25
9:00 – 10:00 a.m.	\$1.95	\$3.25
Afternoon (p.m.)		
2:00 – 3:00 p.m.	\$2.95	\$3.25
3:00 – 4:00 p.m.	\$3.20	\$3.25
4:00 – 5:00 p.m.	\$3.35	\$3.25
5:00 – 6:00 p.m.	\$3.35	\$3.25
6:00 – 7:00 p.m.	\$3.20	\$3.25
7:00 – 8:00 p.m.	\$2.25	\$3.25

While all routes other than the SR-91 and Eastern tollways can be traveled without paying a toll, the only “free” alternative explicitly represented in the choice model is the SR-91 free route. It is assumed that the SR-91 free lanes operate in equilibrium with competing free routes such that there is no travel time advantage to be gained by

¹ The tolls shown here represent the combined toll in fall 1999 for passing through the Windy Ridge Toll Plaza and the Irvine Ranch Toll Plaza. Current toll schedule information is available from www.tcagencies.com, accessed July 28, 2003.

switching from the SR-91 free route to an adjacent arterial. Thus, any route that coincides with the arterial streets adjacent to the SR-91 tollway is free and not tollway.

Using Survey Data to Identify Revealed Choices and Formulate Choice Sets

One of the goals of the Cal Poly survey was to discover the variety of travel behaviors exhibited by individual commuters. The survey accomplishes this goal with queries regarding the most recent a.m. or p.m. trip on Monday through Thursday, plus a second weekday trip if it differed in some material respect, plus questions about travel behavior beyond the recent week. An example of the latter is Question 148² (referred to herein as Q148), which is a multiple-response question that asks:

IN YOUR USUAL PEAK PERIOD TRAVEL, PLEASE TELL ME IF YOU USE ANY OF THE FOLLOWING STRATEGIES TO AVOID TRAFFIC CONGESTION:

- 1. USE TOLL FACILITIES*
- 2. LEAVE EARLY OR LATE TO AVOID PEAK PERIOD CONGESTION*
- 3. JOIN CARPOOL TO USE CARPOOL LANES*
- 4. USE SURFACE STREETS TO AVOID FREEWAY CONGESTION*
- 5. DO NOTHING*
- 6. DON'T KNOW / REFUSED*
- 7. OTHER*

Another example is Question 203 and Question 204, which ask, respectively:

COMPARING YOUR PRESENT TYPICAL PEAK PERIOD TRAVEL TO TWO YEARS AGO, HAS THE OVERALL AMOUNT YOU DRIVE ALONE, CARPOOL, OR TAKE TRANSIT CHANGED?

² This question written by K. Mastako with the goals of this dissertation in mind.

IF IT HAS CHANGED, TYPICALLY, DURING THIS TIME PERIOD DO YOU NOW CARPOOL OR VANPOOL...

1. *MUCH MORE (3+ DAYS PER WEEK)*
2. *A LITTLE MORE (1 – 2 DAYS PER WEEK)*
3. *MUCH LESS*
4. *A LITTLE LESS*
5. *ABOUT THE SAME*
6. *DON'T KNOW / REFUSED*

Specific guidelines for forming the choice sets based on responses to these and other survey questions are presented in the four sections that follow. The basic rules for choice set formation are followed by individual lists of survey questions that give evidence of shoulder and rideshare travel.

Rules for Choice Set Formation

The rules for choice set formation are as follows:

- For a given individual n the estimation process begins with the assumption of the minimum choice set $C'_n = M_1 \equiv \{Endure, Pay\}$.
- If there is evidence in the survey data of rideshare travel but there is no evidence of shoulder travel, then Carpool enters the choice set and the choice set expands to $C'_n = M_2 \equiv \{Endure, Carpool, Pay, Carpool \& Pay\}$.
- If there is evidence of shoulder travel but no evidence of rideshare travel, then Shift enters the choice set and the choice set expands to $C'_n = M_3 \equiv \{Endure, Pay, Shift, Shift \& Pay\}$.
- If there is evidence of rideshare travel *and* there is evidence of shoulder travel, then both Carpool and Shift enter the choice set and the choice set expands to

the full 8-element universal choice set

$$C'_n = M_4 \equiv M \equiv \{Endure, \dots, Shift \& Carpool \& Pay\}.$$

Time Shift Alternatives & Choice Set

There is evidence of shoulder travel if the individual reveals that he:

1. leaves early or late to avoid peak period congestion as part of his usual peak period travel (Q148),
2. crossed the county line before or after the middle of the peak period for the most recent peak period Monday through Thursday trip (Q35 & Q41),
3. crossed the county line before or after the middle of the peak period for another weekday peak period trip that week (Q66 & Q72), or
4. now arrives at his destination earlier or later than he did two years ago because traffic is worse or to avoid higher tolls (Q136 & Q137).

If individual n does not reveal himself to have traveled in the shoulder period in response to these survey questions, it is assumed that he has no history of shoulder period travel and the Shift alternative does not enter his choice set. While the above questions go a long way towards discovering whether an individual has a history of shoulder period travel, they are not comprehensive in this respect. There were many study objectives for the telephone survey and the questionnaire was too long to include additional questions about the frequency with which commuters travel during particular time periods. As a consequence, the absence of a positive revelation with respect to n 's shoulder period travel is not sufficient to declare with certainty that there is no actual history of shoulder period travel. Nonetheless, there is good reason to believe that few shoulder period choices will go undetected by the above listed questions. The person who has chosen shoulder period travel but did not respond positively to Q148 probably failed to respond positively because his times are set and are not chosen for the purpose

of avoiding congestion. Assuming that most fixed schedules are repeating schedules, there is a high probability the Shift alternative will enter the individuals' choice set on the basis of the time he crossed the county line for his recent trip(s).

Of the 939 respondents in the sample, 60.3% of women and 58.9% of men³ revealed, in response to Q148, that they leave early or late to avoid peak period congestion as part of their usual peak period travel. Another 7.1% of women and 8.2% of men described at least one recent trip in which they traveled outside the 4-hour peak or reported that they now travel earlier or later than they did two years ago. The final outcome is that shoulder period travel is added to the choice set of 67.4% of women and 67.1% of men.

Carpool Alternatives & Choice Set

There is evidence of rideshare travel if the respondent reveals that he:

1. uses carpool lanes to avoid congestion as part of his usual peak period travel (see survey question Q148),
2. traveled with at least one other person for the most recent peak period Monday through Thursday trip (Q30),
3. traveled with at least one other person for another weekday peak period trip that week (Q61),
4. travels by carpool for his morning peak period travel more now than he did two years ago (Q115 & Q204), or
5. travels by carpool for his evening peak period travel more now than he did two years ago (Q203 & Q204).

If individual n does not reveal himself to have previously traveled by rideshare in response to the above questions, it is assumed that he has no history of rideshare travel

³ Proportions based on observations weighted according to mode-time shares as described in Section 7.

and the Carpool alternative does not enter his choice set. The above questions are not comprehensive in that they do not fully capture an individual's history of mode choice when the individual carpool for reasons other than avoiding congestion, or carpools but doesn't use the carpool lanes, or misinterprets Q148 to exclude household-based carpools. Thus, the absence of a positive revelation with respect to n 's use of rideshare is not sufficient to declare with certainty that n does not have a history of ridesharing. While there is no way to know how many rideshare choices are undetected using the above methodology, it is reasonable to assume that only a few travelers who occasionally travel with another occupant failed to respond positively to Q148, *and* did not happen to rideshare at all in the recent week, *and* continue to rideshare with the same frequency as two years ago.

Of the 939 respondents, 31.4% of women and 24.1% of men revealed in response to Q148 that they use carpool lanes to avoid congestion as part of their usual peak period travel. An additional 18.8% of women and 6.6% of men described at least one recent trip in which they traveled with another person or revealed that the overall amount that they carpool now compared to two years ago has increased by one or two days per week. The final outcome is that carpool is added to the choice set of 50.2% of the female respondents and 30.7% of the male respondents.

Based on the procedures and criteria outlined in this and the previous section, the next section estimates the considered choice set for each sampled individual and subdivides the sample based on choice set.

11 CHOICE SET RESULTS

The previously described methodology is used here to estimate each survey respondent's considered choice set. This is the step that sets the stage for choice set based market segmentation; the step that sets this research apart from other empirical models of value pricing. Rather than try to explain between-person differences in value priced behavior based solely on socioeconomic and locational characteristics, this study aims to also differentiate users according to the alternatives they actually consider to be feasible. To accomplish this, a simple and inexpensive method for choice set formation is employed for the purpose of labeling each sampled individual according to whether or not he considers ridesharing and / or shoulder period travel to be feasible. Ultimately, potential differences in choice behavior *given choice set* are explored beginning in Section 12. It is hypothesized, for example, that travelers who consider just one option for avoiding recurrent congestion (i.e., tollway travel) may be more willing to trade money for travel time savings than travelers who consider several alternatives (e.g., avoiding the peak period, traveling with others in carpool lanes). In the final stage of the analysis (see Section 14), segment-specific choice models are estimated and the null hypothesis of no taste variations across the four segments is tested.

As previously stated, there are four possible choice sets, M_1 , M_2 , M_3 , and M_4 , where:

$$M_1 = \{Endure, Pay\}$$

$$M_2 = \{Endure, Carpool, Pay, Carpool \& Pay\}$$

$$M_3 = \{Endure, Pay, Shift, Shift \& Pay\}$$

$$M_4 = M = \{Endure, Carpool, Pay, ..., Shift \& Carpool \& Pay\}$$

Each element in the choice sets is a multidimensional alternative as previously defined (see Table 9.1 on page 104). Each individual with $C'_n = M_1$ is labeled as an Endurer.

Each individual with $C'_n = M_2$ is labeled as a Carpooler, each individual with $C'_n = M_3$

is labeled as a Shifter, and each individual with $C'_n = M_4$ is labeled as an Avoider. Thus, Endurers choose from the smallest choice set, equal to the minimum choice set M_1 and Avoiders choose from the largest choice set, equal to the universal choice set M . Avoiders and Carpoolers share a common characteristic; both consider ridesharing as feasible. The difference between Carpoolers and Avoiders is that Carpoolers do not also consider shoulder period travel as feasible. The union of Carpoolers and Avoiders represents all travelers who consider ridesharing as a feasible mode alternative. Similarly, Avoiders and Shifters share a common characteristic; both consider shoulder period travel as feasible. The union of Avoiders and Shifters represents all travelers who consider shoulder period travel as a feasible time alternative.¹

In the figures that follow, the properties of the color wheel are used to depict the shared characteristics. The color red is reserved for travelers who consider ridesharing as feasible and the color yellow is reserved for travelers who consider shoulder period travel as feasible. Red and yellow combine to make orange. Thus, the color orange specifically represents Avoiders segment, while pure red represents Carpoolers and pure yellow represents Shifters segment. White is reserved for Endurers.

The sampled individuals are grouped according to choice set and the results are listed in Table 11.1 and are shown graphically in the two figures that follow.

¹ As a reminder, nothing has yet been discerned regarding traveler perceptions or choice behaviors with respect to value pricing. The methodology implicitly assumes that tollway travel is viable option for all travelers.

Table 11.1 Four Segments Based on Choice Set

$C_n =$		Unweighted		Weighted ²	
		Female (307)	Male (632)	Female (307)	Male (632)
M_1	Endurers (136)	12.4%	15.5%	11.9%	16.1%
M_2	Carpoolers (87)	12.1%	7.9%	10.8%	6.6%
M_3	Shifters (426)	36.8%	49.5%	38.0%	53.2%
M_4	Avoiders (290)	38.8%	27.1%	39.4%	24.1%
	TOTAL	100%	100%	100%	100%

The choice set estimation finds that *no more* than 11.9% of women and 16.1% of men have a choice set equal to the minimum choice set (M_1). These proportions are reported as the upper bounds for these figures because, as previously explained in Section 9, the choice set formation model necessarily *overestimates* the size of the Endurer subpopulation. This finding, which suggests that a relatively small portion of SR-91

² Just like the analysis in Section 8, the results are tabulated for men and women separately and observations within the two choice-based subsamples are weighted according to the mode-time shares.

corridor travelers perceive that their only commute options are to endure congestion or buy their way out, helps in making a strong case for congestion pricing with free travel for HOVs. It can be interpreted to mean that a majority of commuters exhibit *some* flexibility in their trip making such that in the presence of facility-wide congestion pricing, few users would be in the predicament of having to eliminate a trip if they can't or won't pay tolls.

It can also be seen that *at least* 39.4% of women and 24.1% of men have a choice set equal to the universal choice set $M_4 = M$. These proportions are reported as the lower bounds because, as explained in Section 9, the choice set formation model necessarily *underestimates* the size of the Avoider subpopulation.

By inspection of Figure 11.1, it appears that the proportion of women who consider the universal choice set is greater than the proportion of men who consider the universal choice set. If a *statistically significant* difference is found, this may be an indication that the effect of gender on the choice probabilities is segment specific. In this case, it may be prudent to explore the possibility of a stronger association between gender and choice *given choice set* among Avoiders and Shifters than among Endurers and Carpoolers. An important first step is hypothesis testing, which follows. Ultimately, a market segmentation approach to choice model estimation will be employed (see Section 14).

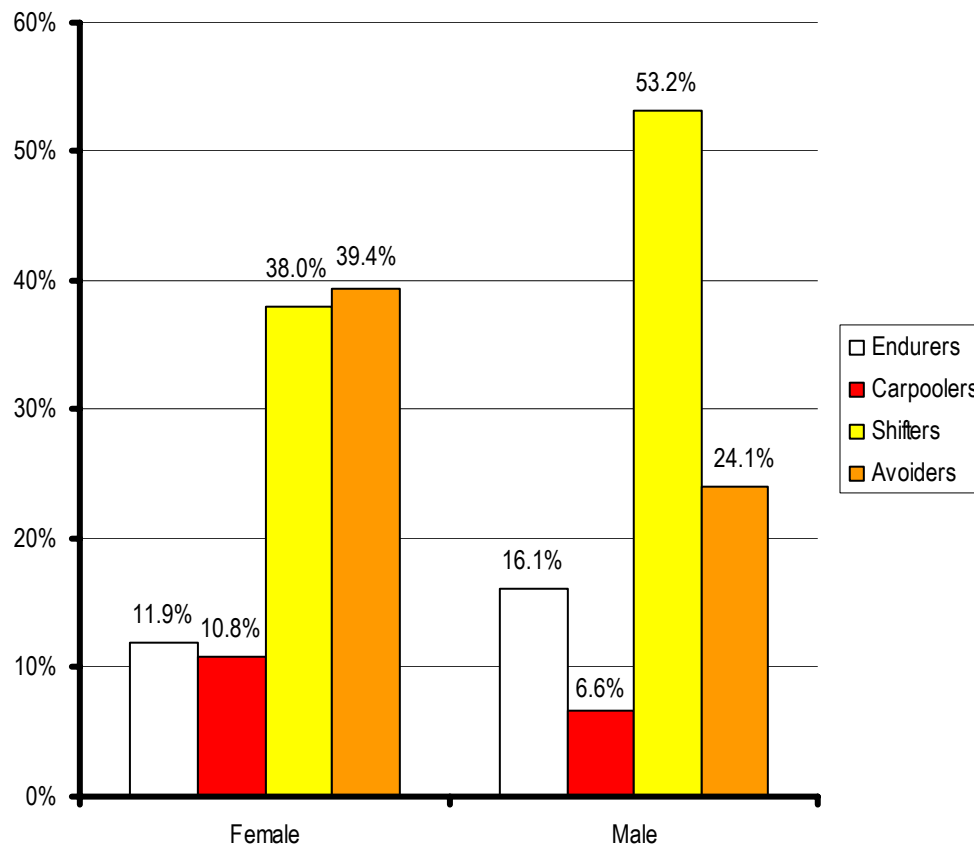


Figure 11.1 Four segments based on choice set

In terms of statistical analysis, categorical data is arranged in two-way contingency tables and preliminary comparisons between socioeconomic groups are conducted. In cases like this, the chi-square test of significance is useful for determining whether or not it is worth the researcher's effort to interpret observed differences. The sample is large enough to support chi-square testing, provided that all cell counts are greater than or equal to five. Chi-square testing is useful to the extent that the test results point out relationships that warrant further investigation; relationships that assist the analyst in the initial specification of the multivariate models (see Section 13 and 14).

First, it is of interest to know if men and women are different in terms of the distribution of choice sets. The null hypothesis that gender and choice set are independent is tested on the weighted observations, and the null hypothesis is rejected at the 10% level ($\chi^2 = 33.6$, $P < 0.001$). As illustrated in Figure 11.1, Shifters and Avoiders are found in approximately proportions among women (38.0% of women are Shifters and 39.4% are Avoiders) but not among men. Among men, Shifters outnumber Avoiders by about 2:1. Similarly, Endurers and Carpoolers are found in equal proportions among women (11.9% of women are Endurers and 10.8% are Carpoolers), but not among men. Among men, Endurers outnumber Carpoolers by about 2.5:1.

The gender-specific choice set distributions are repeated again in Figure 11.2 where the inner ring depicts the choice set distribution for women and the outer ring depicts the choice set distribution for men. The apparent differences between men and women are more clearly seen in this dual-ring representation.³ Based on this figure, it is evident that women are about as likely as men to consider shoulder period travel (orange plus yellow), and are more likely than men to consider ridesharing (red plus orange). A test for associations between household structure and the apparent affinity among women for perceiving the universal choice set follows.

³ In addition to the legend for Figure 11.2, the following color combinations are observed. Beginning at the 12:00 position, white plus red includes all travelers who do not consider shoulder period travel as feasible, red plus orange includes all travelers who consider ridesharing as feasible, and orange plus yellow includes all travelers who consider shoulder period travel as feasible.

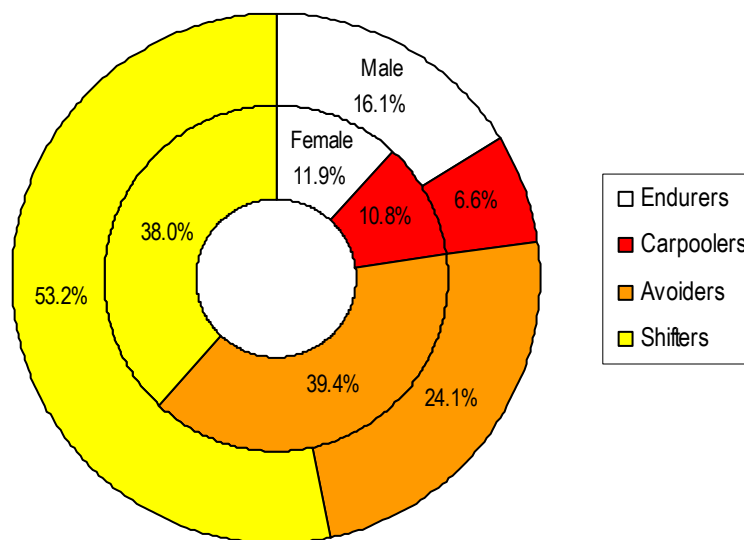


Figure 11.2 Choice set distribution: women (inner ring) vs. men (outer ring)

Choice Set and Household Structure

The association between household structure and choice set is tested on the weighted observations given in Table 11.2. Two household structures are compared: 1) households with children (HH Child), and 2) households without (No Child). For women, the null hypothesis that the two variables are independent is rejected at the 10% level ($P = 0.005$).

Table 11.2 Choice Set and Household Structure

	Women $\chi^2 = 13.0$, P = 0.005		Men $\chi^2 = 5.1$, P = 0.164	
	HH Child	No Child	HH Child	No Child
Endurers	12.0%	11.7%	13.8%	19.7%
Carpoolers	10.2%	11.4%	6.1%	7.4%
Shifters	29.6%	47.2%	56.0%	48.9%
Avoiders	48.1%	29.7%	24.2%	24.0%

As seen in the bottom two rows of Table 11.2, it appears that household structure makes a difference among women in the percentages of Avoiders versus Shifters, but not in the percentages of Carpoolers versus Endurers. The differences are more clearly seen in Figure 11.3 where the inner ring depicts the choice set distribution for women with children and the outer ring depicts the choice set distribution for women without children. The results indicate that among women who do not consider shoulder period travel (white plus red) women with children are as likely as women without children to consider ridesharing. Among women who *do* consider shoulder period travel (orange plus yellow), women with children are *more* likely than women without children to consider rideshare travel. It can be surmised that only among women who consider shoulder period travel is the attribute of household structure associated with perceptions about ridesharing.

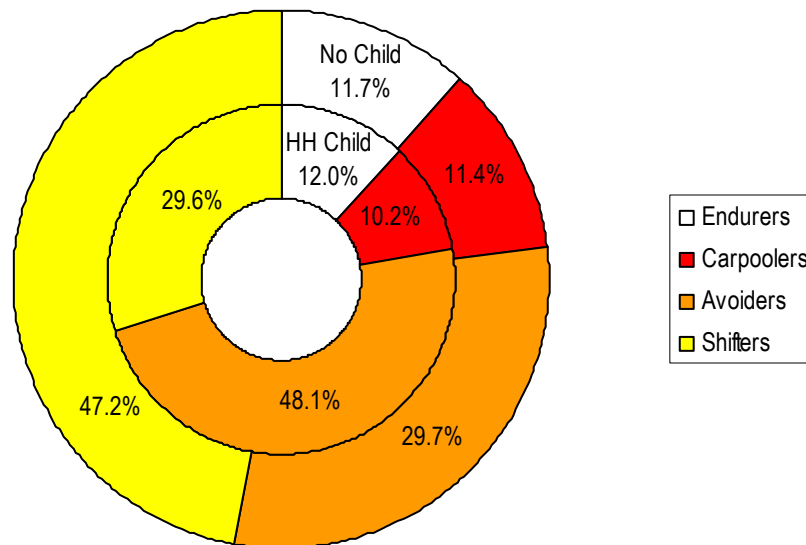


Figure 11.3 Choice set distribution: women with children vs. women without children

By inspection of Table 11.2, it appears that for men, household structure influences the percentage of Endurers versus Shifters. However, the difference is not significant at the 10% level ($P = 0.164$). The same information appears in Figure 11.4 where the inner ring describes men with children and the outer ring describes men without children. Here, it can be seen that men with children are as likely as men without children to consider ridesharing (red plus orange), but appear somewhat more likely to consider shoulder period travel (orange plus yellow). While there are no statistically significant differences between the two groups, the data suggests that for men household structure is more strongly associated with perceptions regarding the time choice dimension, while for women, household structure is more strongly associated with perceptions regarding mode choice.

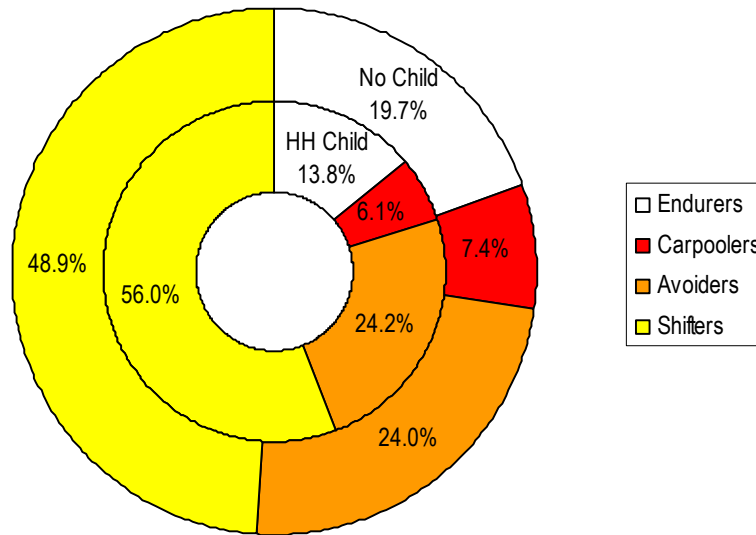


Figure 11.4 Choice set distribution: men with children vs. men without children

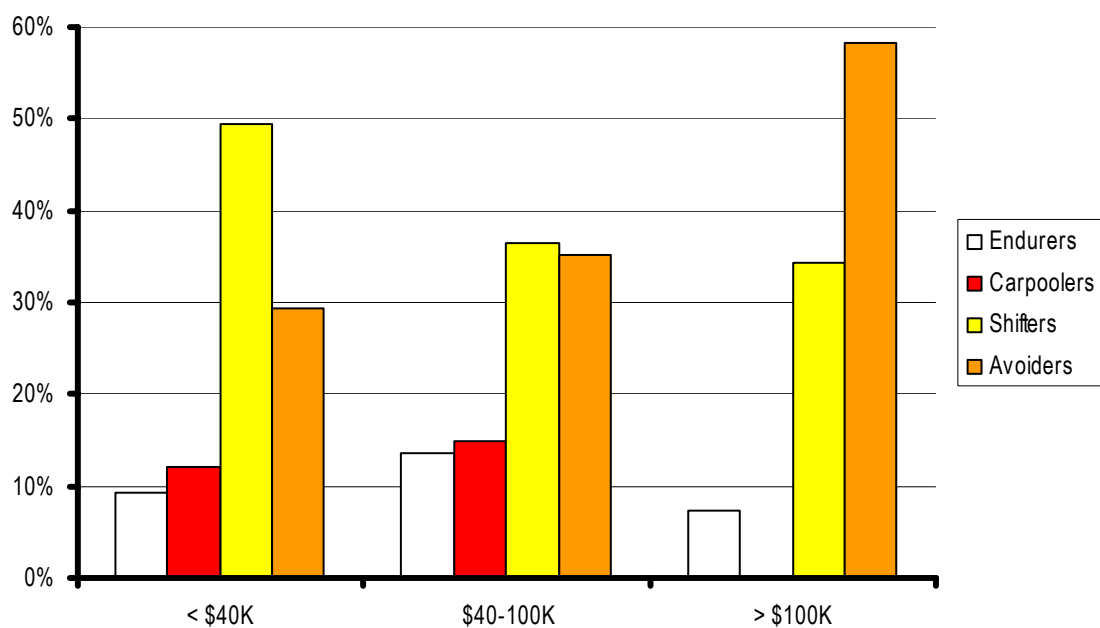
Choice Set and Income

The association between household income and choice set is examined in Table 11.3. The contingency table for women includes a cell with zero observations, making the chi-square test invalid. Nonetheless, the weighted observations are examined in Figure 11.5, where it can be seen that Shifters and Avoiders are found in approximately equal proportions among women in the middle income category. Among women with household incomes < \$40,000, Shifters outnumber Avoiders by about 1.5:1. The opposite relationship is observed for women with household incomes > \$100,000. The reason for this apparent trend toward more Avoiders and fewer Shifters among women as income increases is unknown.⁴ No such relationship is observed for men (i.e., the association between household income and choice set is not significant at the 10% level).

⁴ The percentage of child-at-home households is highest for the \$40 – 100K income group (62.0%) and approximately equal for the < \$40K and > \$100K groups (52.4% and 53.8%, respectively).

Table 11.3 Choice Set and Income

	Women ⁵			Men $\chi^2 = 2.5, P = 0.865$		
	< \$40K	\$40–100K	> \$100K	< \$40K	\$40–100K	> \$100K
Endurers	9.2%	13.5%	7.4%	16.3%	17.5%	14.0%
Carpoolers	12.0%	15.0%	0%	4.7%	5.4%	8.2%
Shifters	49.4%	36.4%	34.4%	52.2%	52.9%	55.3%
Avoiders	29.4%	35.1%	58.2%	26.8%	24.2%	22.5%

**Figure 11.5 Women: choice set vs. income**

⁵ No chi-square test results to present. The chi-square test is invalid when one or more cells contains zero observations.

Choice Set and Education

The association between education and choice set is tested in Table 11.4. Two levels of education are compared: 1) having a degree from a four year college (Degree), and 2) not (No Degree). The null hypothesis that the two variables are independent is rejected at the 10% level for women ($P = 0.043$) but not for men ($P = 0.242$).

Table 11.4 Choice Set and Education

	Women $\chi^2 = 8.1, P = 0.043$		Men $\chi^2 = 4.2, P = 0.242$	
	Degree	No Degree	Degree	No Degree
Endurers	13.7%	10.8%	16.6%	16.0%
Carpoolers	5.1%	13.1%	8.0%	5.6%
Shifters	46.1%	33.6%	55.1%	51.6%
Avoiders	35.0%	42.6%	20.3%	26.8%

By inspection of Table 11.4, it can be seen that among women with a degree, Shifters outnumber Carpoolers by approximately 9:1. Among women without a degree, Shifters outnumber Carpoolers by approximately 2.5:1. The same information is shown in Figure 11.6 where the inner describes women with a degree and the outer ring describes women without a degree. Here, it can easily be seen that women with a degree are less likely than women without a degree to consider ridesharing (red plus orange), are more likely to be Shifters (yellow), and about as likely to be Avoiders (white). Among men, education and choice set were found to be independent, as shown graphically in Figure 11.7.

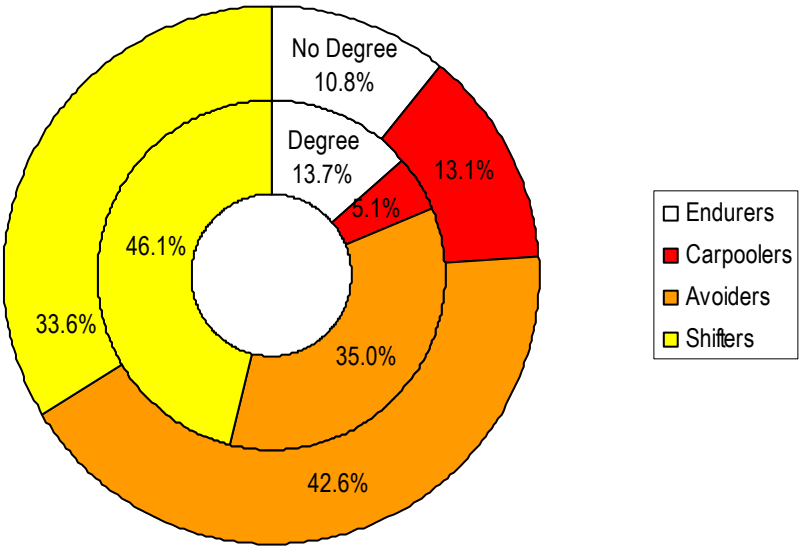


Figure 11.6 Choice set distribution: women with a degree vs. women without a degree

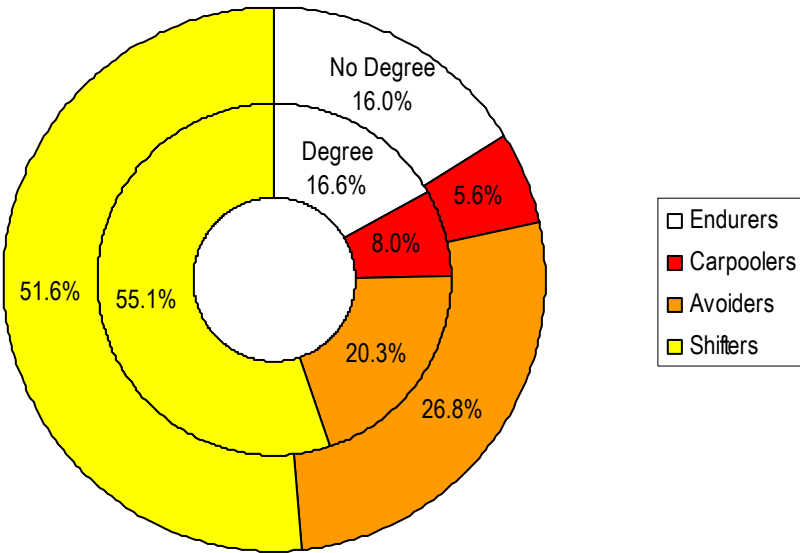


Figure 11.7 Choice set distribution: men with a degree vs. men without a degree

Conclusions Regarding Choice Sets

The preceding analysis points to several conclusions. The primary conclusion is that within the SR-91 corridor, the majority of commuters exhibit some degree of flexibility in their trip making behavior, and the dimensions on which people are flexible are distributed differently among men and women. It is estimated that within the study corridor, 53.2% of men and 38.0% of women are Shifters (i.e., select from the Shifter choice set $M_3 = \{Endure, Pay, Shift, Shift \& Pay\}$). These estimates are admittedly high compared to the true percentages of users who select from the Shifter choice set M_3 rather than the universal Avoider choice set M . As previously stated, the true number of sampled individuals who select from the Shifter choice set is necessarily smaller than the estimate from the employed methodology. Specifically, the true number is smaller by the number of sampled users who have no observed history of ridesharing yet consider ridesharing to be a viable alternative. The results of a 1992 stated preference survey of Orange County drivers by Baldassare et al. (34) suggest that the difference between the true value and the estimate may be minor. The study found that most solo Orange County drivers say they are unlikely to stop driving alone even in the face of cash incentives and fees. If the majority of solo drivers describe themselves as somehow constrained against ridesharing, then it is unlikely that a large number of true Avoiders ($C_n = M$) were misclassified as Shifters ($C'_n = M_3$).

Regardless of the potential for overestimating the proportion of Shifters relative to Avoiders, there appear to be important differences between men and women. Women are found to be more likely than men to choose from the universal choice set. Among the women in the sample, Shifters and Avoiders are found in approximately equal proportions. Among men, Shifters outnumber Avoiders by 2:1. Given that the same heuristic rule set was used for all respondents, any adjustment in terms of

underestimating the true proportion of Avoiders would likely affect men and women equally and the observed disparity between the genders would be preserved.

Several socioeconomic factors including household structure, income, and education, were investigated as potential predictors for choice set. The results suggest stronger associations between these socioeconomic factors and choice set for women than for men. For example, only among women are the attributes of household structure and education associated with choice set. It is hypothesized that for women more than men, perceptions regarding the feasibility of available alternatives, and ridesharing in particular, are shaped more by their activities, especially those associated with household responsibilities. In terms of the model development process, this is an indication for interacting gender attributes with household attributes.

Finally, the results presented in Table 11.1 make a noteworthy contribution in terms of a reasonable approximation on the distribution of choice sets among SR-91 users. Beyond the scope of the current study, the demonstrated methodology can be incorporated elsewhere to determine the probability that individual n considers a particular choice set M_r . For this dissertation, this is a crucial first step towards discovering if choice set is an important predictor for choice behavior in value pricing. With each sampled individual labeled according to whether or not he considers ridesharing and / or shoulder period travel to be feasible, potential differences in choice behavior given choice set can now be explored. It is hypothesized that because Endurers consider just one option for avoiding recurrent congestion, they may be more willing than others to trade money for travel time savings. It is perhaps equally plausible that Avoiders may be more willing than others to trade money for travel time savings either because they consider, for example, the opportunity to split the toll among multiple occupants and also enjoy the usual ridesharing benefits of traveling in carpool lanes, or because they implicitly have a higher value of travel time and have therefore adopted the largest choice set. Ultimately,

segment-specific choice models will be estimated and the null hypothesis of no taste variations across the four segments will be tested.

12 CHOICE GIVEN CHOICE SET

In the previous section, each person's revealed history of mode and time of day choice was used to estimate his or her considered choice set. The sample was then subdivided into four groups (or segments), wherein all members have the same revealed choice set. The current section evaluates the four segments with respect to actual mode, time, *and route* choices for the most recent Monday through Thursday trips.¹ The following are among the questions investigated here:

1. Are Carpoolers more likely than Avoiders to rideshare because they don't consider the option of traveling in a shoulder period?
2. Are Shifters more likely than Avoiders to travel in a shoulder period because they don't consider the option of ridesharing?
3. Are Avoiders more likely than other commuters to pay a toll because they consider opportunities for getting shoulder period discounts and also consider opportunities for splitting the toll among multiple occupants?
4. Are Endurers more likely than other commuters to pay a toll because they consider no other options for bypassing or avoiding congestion?
5. Within a given segment, does the choice of mode or time influence the decision to pay a toll?

The analysis that follows is concerned with "choice given choice set" (i.e., choice conditional on choice set). Herein, all discussion of choice refers to individual n 's choice of alternative j from choice set M_n for the most recent Monday through Thursday study period trip.

¹ Only for a small proportion of respondents did the evidence for estimating the choice set come from statements about their most recent Monday through Thursday trip. For 88.3% of Shifters plus Avoiders, the evidence of shoulder period travel came from Q148. For 71.5% of Carpoolers plus Avoiders, the evidence of rideshare travel came from Q148.

Choice Conditional on Choice Set

For each segment in the study sample, the distribution of choices for the most recent Monday through Thursday trips is given in Table 12.1. In this table, men and women are combined. Combining men and women requires a new set of expansion factors; one that is based on observed mode-time-*gender* shares as given in Table 12.2. Whenever men and women are analyzed separately, the original expansion factors based on observed mode-time shares are used (see Table 7.5 on page 76).

Table 12.1 Choices by Segment with Men & Women Combined

<i>j</i>		Endurers	Carpoolers	Shifters	Avoiders	All
1	Endure	70.0%	18.5%	45.0%	14.5%	37.5%
2	Carpool		45.3%		23.5%	10.7%
3	Pay	30.0%	4.0%	25.7%	11.7%	20.4%
4	Carpool & Pay		32.2%		19.3%	8.4%
5	Shift			21.7%	8.3%	12.7%
6	Shift & Carpool				12.5%	3.7%
7	Shift & Pay			7.6%	3.5%	4.6%
8	Shift & Carpool & Pay				6.7%	2.0%
	TOTAL	100%	100%	100%	100%	100%

Table 12.2 Expansion Factors Based on Mode-Time-Gender Shares

	Random	Panel	Plates
MALE			
Rideshare-Shoulder	1.000	1.208	0.845
Rideshare-Peak	1.000	0.533	0.578
Solo-Shoulder	1.000	1.657	1.072
Solo-Peak	1.000	1.106	0.900
FEMALE			
Rideshare-Shoulder	1.000	2.416	2.815
Rideshare-Peak	1.000	0.776	1.114
Solo-Shoulder	1.000	0.920	2.758
Solo-Peak	1.000	0.994	1.277

The data in Table 12.1 can be used to examine route choice behavior, for example. For a given segment, the proportion that reported using a tollway is shown in Figure 12.1.

These figures are derived directly from Table 12.1 by summing the percentages associated with each tollway (or Pay) alternative ($j = 3, 4, 7, 8$).² By inspection of Figure 12.1, it can be seen that the proportion of Avoiders who used a tollway for their most recent trip (41.2%)³ is greater than the proportion of Endurers who used a tollway (30.0%). With respect to all four segments, the null hypothesis that route choice and

² Table 12.1 is referred to repeatedly throughout this section for the purpose of extracting the relevant proportions. It will become apparent that the data in Table 12.1 can be analyzed in many different and overlapping ways. The analysis presented herein is comprehensive such that certain patterns may repeat, though every effort is made to minimize redundant information.

³ From Table 12.1, $11.7 + 19.3 + 3.5 + 6.7 = 41.2\%$.

choice set are independent is rejected at the 10% level with $\chi^2 = 6.72$ ($P = 0.081$). One *possible* interpretation is that Carpoolers and Avoiders are more likely than Endurers and Shifters to use tollways because they can split the toll among multiple occupants and can chain together the time saving benefits of tollway travel with the time saving benefits of traveling in available carpool lanes.

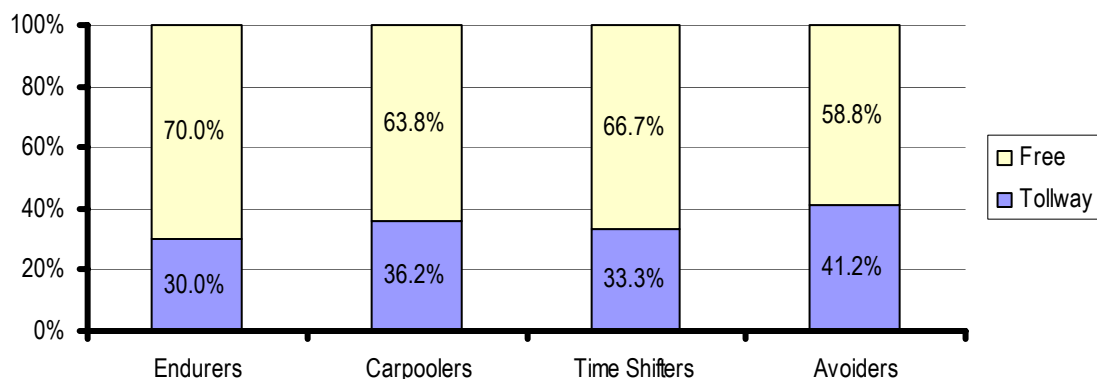


Figure 12.1 Choice of free vs. tollway, all segments

Ultimately, pairwise comparisons among the four segments are conducted with statistical testing for the purpose of identifying other potentially important relationships between choice and choice set. For example, it is of interest to compare Carpoolers versus Shifters because both groups consider opportunities for “discounted” tolls. For Carpoolers, the Carpool & Pay alternative may be an opportunity to split the toll among multiple occupants. For Shifters, the Shift & Pay alternative may be an opportunity for tollway travel at less than the full peak period price.

Prior to pairwise testing, the four groups are evaluated in terms of the effect that a person’s gender may have on their choice probabilities. It is hypothesized that gender may be an important determinant of choice behavior for some but not all market

segments. If the hypothesis is true, then the segment-specific model specification would be expected to reflect this (see Section 14).

Throughout this section, statistical testing is used to test various hypothesis regarding choice and choice set. Whenever the result of the test is to suggest a difference in revealed choice behavior among choice set groups, there is an opportunity to formulate a conjecture about the reason for the difference. Without any evidence to support the statement, the statement is purely speculative. In these cases, the phrase “one possible explanation...” is used to acknowledge the conjecture and admit to others not explicitly stated, only because the author did not identify them.

Is Choice Given Choice Set Independent of Gender?

A number of empirical studies have demonstrated an association between gender and tollway use in value pricing including Supernak et al. (58), Brownstone et al. (13), Sullivan (44), and Yan et al. (41).⁴ Still, the reasons for observed gender differences are largely unknown. It has already been suggested in Section 8 that gender may *not* be a strong predictor of tollway use among Carpoolers. Even though the overall proportion of users who chose tollway travel for a given trip is generally higher for women than for men, there appears to be a connection between mode and route choice that is demonstrated only by men (as revealed in the analysis of data in Table 8.13 and Table 8.14). The condition that men who carpool are more likely to use tollways than men who drive alone, while women who carpool are *no more likely* to use tollways than women who drive alone may effectively “wipe out” any gender difference in route choice among Carpoolers.

⁴ One exception is Li (38) who concludes that gender “makes no significant differences in HOT lane use after controlling for other important explanatory variables.”

The question of whether or not gender and choice given choice set are independent is addressed in detail for a limited number of cases in order to demonstrate the analytical method. Following this demonstration, the results of statistical testing for gender differences across all segments (and all applicable choice dimensions) are summarized in Table 12.3.

Choice Given the Carpooler Choice Set, Men vs. Women

Figure 12.2 is used to compare male and female Carpoolers for the proportions using each of the four *considered* alternatives. With very few Pay ($j = 3$) observations among Carpoolers, the chi-square test is not valid for comparing male and female Carpoolers across all four considered alternatives. The chi-square test is invalid for this particular 4 x 2 contingency table because too many (i.e., more than 20%) of the expected cell frequencies are less five. By inspection, it appears that the proportion of male Carpoolers who shared a ride (75.1%⁵ in yellow plus aqua) is about the same as the proportion of female Carpoolers who shared a ride (79.3%). These composite figures allow a more compact 2 x 2 contingency table specific to mode choice for which the chi-square test is valid. The null hypothesis that among Carpoolers, gender and ridesharing are independent is not rejected at the 10% level ($\chi^2 = 0.19$, $P = 0.659$). This test result suggests that in the context of route choice *given the Carpooler choice set*, men are as likely as women to actually share a ride. Given that gender was previously shown to be associated with ridesharing within the overall population,⁶ this finding points to potential differences among segments regarding the role of gender in determining choice probabilities.

⁵ From Figure 12.2, $40.8 + 34.3 = 75.1\%$.

⁶ In the pooled sample with all four segments combined, the same null hypothesis *is* rejected with $\chi^2 = 38.6$, ($P < 0.001$), wherein 36.2% of all women shared a ride versus 17.8% of all men.

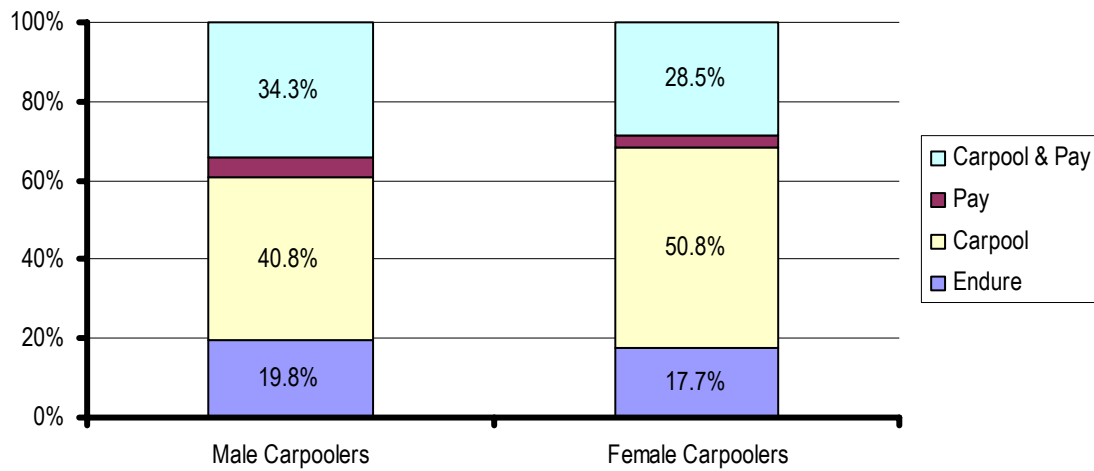


Figure 12.2 Revealed choices, male vs. female carpoolers

A similar phenomenon is detected with respect to route choice. In the *pooled* sample, the proportion of women who used a tollway (43.7%) is greater than the proportion of men who used a tollway (30.5%). Based on these figures, gender is shown to be associated with route choice at the 10% level ($\chi^2 = 16.0$, $P < 0.001$). Among Carpoolers however, the proportion of women who used a tollway (31.5%) is actually *smaller* than the proportion of men who used a tollway (39.4%). Among Carpoolers, the null hypothesis that gender and route choice are independent is not rejected at the 10% level ($\chi^2 = 0.50$, $P = 0.479$). Though gender appears to be associated with both mode and route choice within the overall population, the current analysis finds no indication that gender is associated with either mode or route choice among Carpoolers. It appears that for people who have the Carpooler choice set there is no gender difference in mode preference.

Choice Given the Shifter Choice Set, Men vs. Women

The choice split information in Figure 12.3 is similar to Figure 12.2 except that it is specific to Shifters and the unique set of four alternatives that Shifters consider. In this

case, the chi-square test *is* valid for comparing male and female Shifters across all four alternatives. The null hypothesis that the distribution of choices among the four considered alternatives is the same for male Shifters and female Shifters is rejected at the 10% level ($\chi^2 = 14.4$, $P = 0.002$). It was previously concluded that gender is not associated with route choice among Carpoolers. The opposite is true for Shifters. As shown in plum plus peach, the proportion of female Shifters who used a tollway (46.3%) is greater than the proportion of male Shifters who used a tollway (27.9%). Compared to female Shifters, a greater proportion of male Shifters chose Endure or Shift rather than pay to use a tollway.

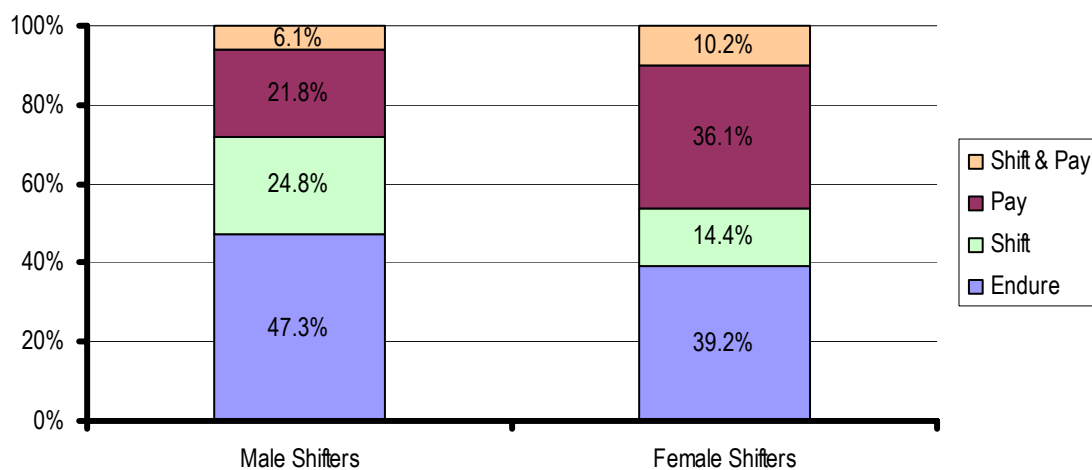


Figure 12.3 Revealed choices, male vs. female shifters

The gender-specific analyses demonstrated in connection with Figure 12.2 for Carpoolers and Figure 12.3 for Shifters is repeated for each segment and each applicable choice dimension. The results are summarized in Table 12.3. As shown by the P-values in the first row, the null hypothesis that gender and route choice are independent is *initially* rejected at the 10% level for Shifters and Avoiders, but not for Endurers and

Carpoolers. A modified conclusion is formulated after the potential for committing a Type I error is addressed (immediately below).

Table 12.3 Gender and Choice, Tests of Independence

	All	Endurers	Carpoolers	Shifters	Avoiders
Route: Tollway vs. Free	$\chi^2 = 16.0$ P < 0.001*	$\chi^2 = 1.4$ P = 0.237	$\chi^2 = 0.5$ P = 0.479	$\chi^2 = 13.3$ P < 0.001*	$\chi^2 = 2.9$ P = 0.089*
Mode: Rideshare vs. Solo	$\chi^2 = 38.6$ P < 0.001*		$\chi^2 = 0.2$ P = 0.659		$\chi^2 = 8.0$ P = 0.005*
Time: Shoulder vs. Peak	$\chi^2 = 0.5$ P = 0.460			$\chi^2 = 1.6$ P = 0.200	$\chi^2 < 0.1$ P = 0.933

* H_0 rejected at the 10% level.

A commonly identified issue with the chi-square test is that when sample sizes are small, there is a tendency to reject the null hypothesis when the null hypothesis is true (51, p. 362). In other words, when sample sizes are small there is a tendency to make what is commonly referred to as a Type I error. Yates' correction, which removes this tendency, generates a smaller χ^2 value with a correspondingly larger P-value. The only test in Table 12.3 that is a candidate for applying Yates' correction is route choice among Avoiders, shown in the upper right corner of the table. This is the only candidate because it is the only instance of rejecting the null hypothesis with a P-value not much smaller than 0.10. With the Yates' correction, $\chi^2 = 0.25$ and P = 0.115, and the null hypothesis is *not* rejected at the 10% level, calling into question the role of gender in determining route choice among Avoiders. While gender may be an important predictor for route choice for Shifters, it is not clear that the same is true for other users.

Conclusions regarding Gender and Choice Conditional on Choice Set

The preceding analysis suggests that gender is a predictor of choice given choice set only for some types of travelers. Especially among Endurers and Carpoolers, it appears that men and women make similar choices regarding tollway use. This is a noteworthy finding that will be investigated further and should ultimately be reflected in the model estimation work. It is plausible that for some users, gender may be more strongly associated with choice set formation than with choice given choice set. Once choice sets are formed, other factors may be more important in determining choice behavior conditional on choice set (including the size of the choice set). In estimating segment-specific models, it is expected that gender may be a stronger explanatory variable for Shifters than for Carpoolers and Endurers.

This dissertation does not aim to identify, in relation to the presence or absence of gender-specific taste variations for choice given choice set, the particular constraints that might shape a person's choice set. Clearly, there are opportunities in future research to explore the connections between specific lifestyle and attitudinal constraints, choice set, and choice behavior for value pricing.

Before moving forward to model estimation, additional comparisons are needed to address the questions posed at the start of this section. The analysis continues by comparing the segments in a pairwise manner. Carpoolers and Avoiders are compared in terms of mode and route choice, Shifters and Avoiders are compared in terms of time and route choice, and Carpoolers and Shifters are compared in terms of route choice.

As demonstrated in the discussion of Table 12.3, the P-value (P) is useful for interpreting the results of the chi-square test of independence. Giving the P-value is often preferable to reporting the chi-square test statistic and the critical value for a given level of significance. The P-value is helpful for interpreting results because it reveals something about the weight of the evidence for rejecting or failing to reject the null

hypothesis. In this manner, the P-value is also sufficient. It is a function of chi-square test statistic and the number of degrees of freedom, and can be interpreted for any desired level of significance (47, p. 231). The latter attribute is especially useful when the stated level of significance for rejecting the null hypothesis is based as much on a tradition of research as it is based on thoughtful deliberation. From this point forward, the chi-square value is omitted in reporting results of hypothesis testing. Where applicable, Yates' correction is applied and explicitly stated. Otherwise, only the unadjusted P-value is given.

Carpoolers vs. Avoiders

Carpoolers and Avoiders are similar in that both have ridesharing in their revealed history of travel behavior and are assumed to consider sharing a ride with at least one other person as a feasible method of travel. Comparisons are made here between Carpoolers and Avoiders regarding mode and route choices for the most recent Monday through Thursday trips. Compared to Carpoolers, Avoiders have a larger choice set and may be less likely to use tollways or share a ride. On the other hand, Avoiders may be more likely than Carpoolers to use tollways either because they also consider the opportunity to get shoulder period discounts on tollway travel, or because they inherently have stronger preferences for not traveling in congested traffic conditions (i.e., higher values of time), and that is the reason they consider larger choice sets.

Mode Choice

From the data in Table 12.1 on page 140, 77.5%⁷ of Carpoolers versus 62.0%⁸ of Avoiders shared a ride with at least one other person. The null hypothesis that mode choice is independent of these choice sets (i.e., Carpooler versus Avoider) is rejected at the 10% level ($P = 0.011$). One *possible* explanation is that Carpoolers are more likely than Avoiders to share a ride because they are more sensitive to the cost savings (e.g.,

⁷ From Table 12.1, $45.3 + 32.2 = 77.5\%$.

⁸ From Table 12.1, $23.5 + 19.3 + 12.5 + 6.7 = 62.0\%$

fuel, vehicle wear and tear) and/or the environmental benefits (e.g., emissions). Another possible explanation is that Avoiders are less likely to share a ride, simply because they have larger choice sets.

The comparison between Carpoolers and Avoiders is illustrated separately for men and women in Figure 12.4. For each group of decision makers, the primary figure of interest is the proportion that reported sharing a ride for their most recent trip, regardless of whether or not ridesharing was combined with tollway or shoulder period travel. This is the figure shown in blue, which represents the sum of all rideshare (or Carpool) alternatives ($j = 2,4,6,8$). When men and women are analyzed separately in this respect, the null hypothesis that mode choice is independent of choice set (Carpooler versus Avoider) is rejected at the 10% level for men ($P = 0.012$) but not for women ($P = 0.301$).

In terms of mode choice for a given choice set, female Avoiders and female Carpoolers appear to behave similarly, whereas male Avoiders and male Carpoolers do not. Of particular interest, is the apparently unique mode choice behavior of male Avoiders. Compared to the other rideshare-considering groups depicted in Figure 12.4, male Avoiders appear least likely to actually share a ride. It is plausible that among men but not women, the circumstances that lead a Carpooler to consider ridesharing as feasible are different than the circumstances that lead an Avoider to consider ridesharing as feasible, and that these circumstances influence not only choice set formation but also choice behavior given choice set. One *possible* explanation is that for male Carpoolers, perceptions of ridesharing may have more to do with preferences for not traveling in congested travel conditions, while for male Avoiders, perceptions of ridesharing may have more to do with their activities, including household responsibilities.

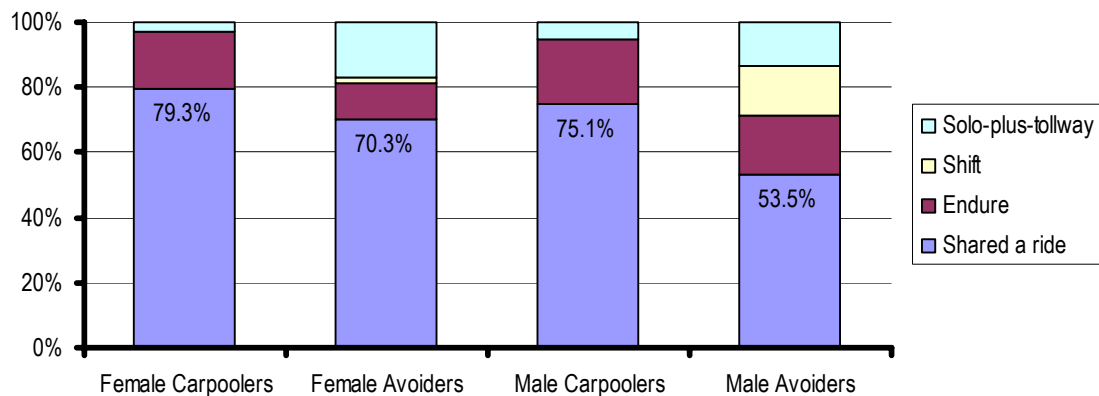


Figure 12.4 Carpoolers vs. avoiders, proportion choosing rideshare alternatives

The remaining colors in Figure 12.4 represent usage of considered solo alternatives. Partly because Avoiders have four considered solo alternatives ($j = 1, 3, 5, 7$) while Carpoolers have two ($j = 1, 3$), it is convenient to aggregate the Pay ($j = 3$) and Shift & Pay ($j = 7$) observations into one figure, referred herein to as Solo-plus-tollway and shown in aqua. The only reason for combining these observations is to facilitate a meaningful interpretation of the data by reducing the number of data points to report. As shown, male Avoiders are approximately evenly split between Endure (17.9% shown in plum), Shift (15.0% shown in yellow), and Solo-plus-tollway (13.6% shown in aqua). Among female Avoiders, the proportion observed choosing the Shift alternative (1.6% shown in yellow) is substantially smaller than the proportions observed choosing the other two. This suggests that more male Avoiders than female Avoiders favor Shift as a substitute for ridesharing. In Figure 12.4, it can also be seen that most male and female Carpoolers who did not share a ride chose Endure (plum) over Pay (aqua). By inspection of Table 12.1 on page 140 it appears that among the four segments, Carpoolers are the *least* likely to choose the Pay alternative ($j = 3$).

Route Choice

If shoulder period use of tollways saves enough time to compensate the user for the shoulder period toll, then due to the additional considered alternative of combining shoulder travel with tollway travel, Avoiders might be more likely than Carpoolers to use tollways. Based on the data given in Table 12.1, it can be seen that 36.2%⁹ of Carpoolers chose tollway travel versus 41.2%¹⁰ of Avoiders. The null hypothesis that route choice and choice set (Carpooler versus Avoider) are independent is not rejected at the 10% level ($P = 0.435$, when men and women are combined).

In Figure 12.5, men and women are analyzed separately. The primary figure of interest is the proportion that reported using a tollway for their most recent trip, regardless of whether or not tollway travel was combined with ridesharing or shoulder travel. This is the figure shown in blue, which represents the sum of all tollway (or Pay) alternatives ($j = 3, 4, 7, 8$). As shown, the proportion of female Avoiders who chose tollway travel (46.7%) is greater than the proportion of female Carpoolers who chose tollway travel (31.5%), but the difference is not significant at the 10% level ($P = 0.116$; with the Yates' correction, $P = 0.170$). Surprisingly, there is no statistical evidence to suggest that Avoiders are more likely than Carpoolers to use tollways.

⁹ From Table 12.1, $4.0 + 32.2 = 36.2\%$.

¹⁰ From Table 12.1, $11.7 + 19.3 + 3.5 + 6.7 = 41.2\%$.

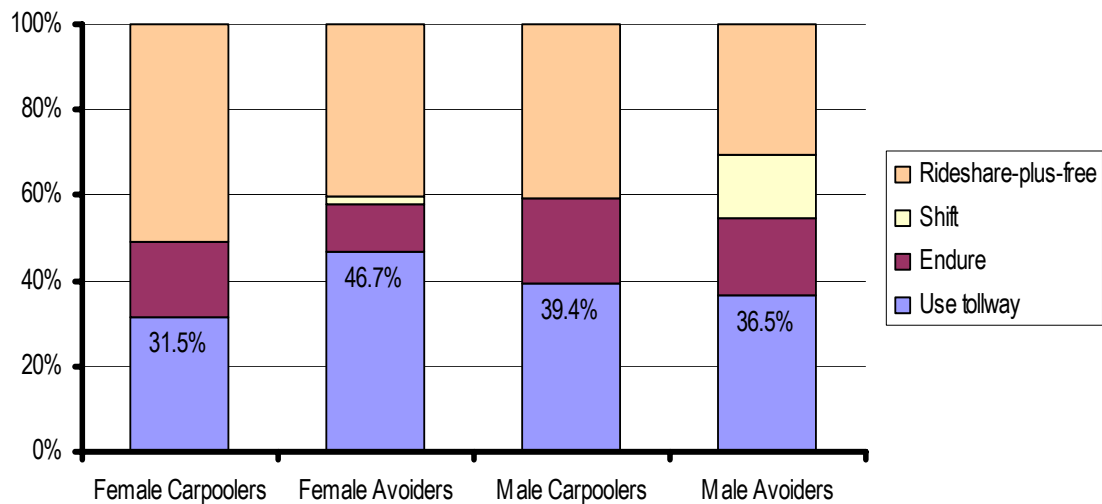


Figure 12.5 Carpoolers vs. avoiders, proportion choosing tollway alternatives

The remaining colors in Figure 12.5 represent usage of considered free alternatives. For the purpose of facilitating a meaningful interpretation, Carpool ($j = 2$) and Shift & Carpool ($j = 6$) observations are combined into one figure, referred herein to as Rideshare-plus-free and shown in peach. This suggests that more male Avoiders than female Avoiders favor Shift as a substitute for using tollways. Together, Figure 12.4 and Figure 12.5 indicate that among Avoiders, women are more likely than men to combine shoulder travel with tollway travel or ridesharing. One *possible* explanation is that women more than men perceive non travel time benefits of tollway travel (e.g., comfort and safety) and are thus more likely than men to choose tollway travel during shoulder periods when congestion on the free routes is less of a problem.

Figure 12.6 seeks further insight by taking a close look at the ways Avoiders use tollways. In essence, Figure 12.5 is a “blowup” view of the second and fourth of the blue bars in Figure 12.5. In the blowup views, all four tollway alternatives ($j = 3,4,7,8$) are separately represented. As shown, 30.8% of female Avoiders who used a tollway

also traveled in a shoulder period (plum plus peach) compared to 19.7% of male Avoiders. These proportions are not significantly different at the 10% level ($P = 0.180$). Independent of route choice, male Avoiders are as likely as female Avoiders to be traveling in a shoulder period. A different view of the data, which examines Avoiders traveling in shoulder periods, is given in the following analysis of Shifters versus Avoiders.

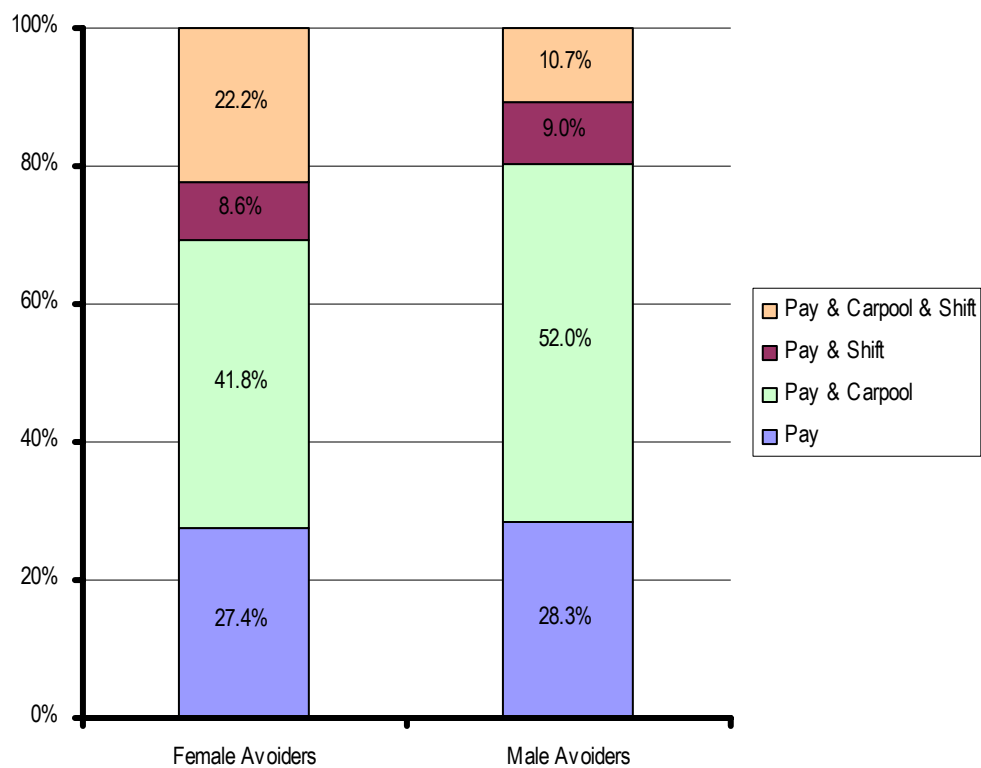


Figure 12.6 Male vs. female avoiders, ways of using tollways

Shifters vs. Avoiders

Shifters and Avoiders are similar in that both consider shoulder periods as being feasible for their travel. The only difference is that the latter also considers ridesharing to be

feasible. Comparisons are made here between Shifters and Avoiders regarding time and route choice for the most recent trip. Compared to Shifters, Avoiders have a larger choice set and may be less likely to pay a toll or travel in a shoulder period. On the other hand, Avoiders may be more likely than Shifters to use tollways either because they also consider the opportunity to split the toll with other occupants, or because they inherently have stronger preferences for not traveling in congested traffic conditions (i.e., higher values of time), and that is the reason they consider larger choice sets.

Time Choice

From Table 12.1 on page 140, 29.3%¹¹ of Shifters and 31.0%¹² of Avoiders traveled in a shoulder period¹³ for their most recent trip. The null hypothesis that time choice is independent of choice set (Shifter versus Avoider) is not rejected at the 10% level ($P = 0.607$). Even though Avoiders may consider a more diverse set of alternatives, it appears that Avoiders are as likely as Shifters to travel in a shoulder period. The comparison between Shifters and Avoiders is illustrated separately for men and women in Figure 12.7. In this chart, the primary figure of interest given in blue is the proportion that reported traveling in a shoulder period, regardless of whether or not shoulder travel is combined with sharing a ride or using a tollway. As shown, 24.6% of female Shifters versus 31.4% of female Avoiders traveled in a shoulder period. This difference is not significant at the 10% level ($P = 0.244$).

¹¹ From Table 12.1, $21.7 + 7.6 = 29.3\%$.

¹² From Table 12.1, $8.3 + 12.5 + 3.5 + 6.7 = 31.0\%$.

¹³ As previously defined, shoulder period travel is crossing the county line 4:00 – 5:00 a.m., 9:00 – 10:00 a.m., 2:00 – 3:00 p.m. or 7:00 – 8:00 a.m.

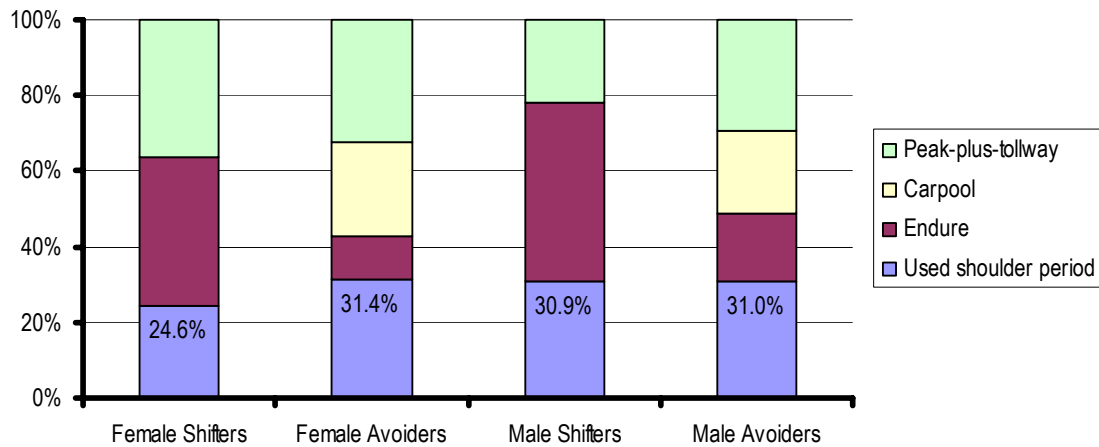


Figure 12.7 Shifters vs. avoiders, proportion choosing shoulder period alternatives

The remaining colors in Figure 12.7 represent usage of considered peak alternatives, $j = 1, 2, 3, 4$ for Avoiders and $j = 1, 2$ for Shifters. For ease of interpreting the chart, Pay ($j = 3$) and Carpool & Pay ($j = 4$) observations are combined into one figure, referred to herein as Peak-plus-tollway and given in green. As shown, female Shifters are approximately evenly split between Endure (39.2% shown in plum) and Pay (36.1% shown in green). Among male Shifters, Endure observations (47.3% shown in plum) outnumber Pay observations (21.8% shown in aqua) by about 2:1.

Figure 12.8 seeks new insight by taking a close look at the ways Avoiders travel in shoulder periods. Figure 12.8 is a “blowup” view of the second and fourth of the blue bars in Figure 12.7. In this “blowup” view, all four shoulder alternatives ($j = 5, 6, 7, 8$) are separately represented. Because the figure is specific to a given time period, it requires a different set of expansion factors based on observed mode shares, instead of observed mode-time shares as given earlier in Table 7.5. The expansion factors based on observed mode shares are given in Table 12.4 on page 157.

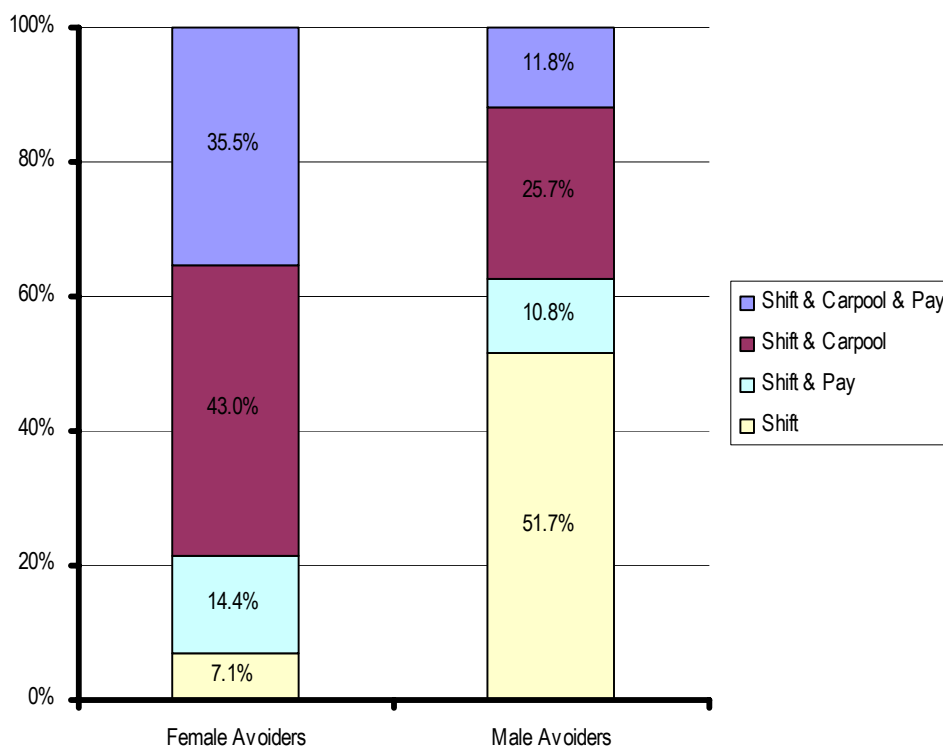


Figure 12.8 Male vs. female avoiders, ways of using shoulder period travel

Table 12.4 Expansion Factors Based on Mode Shares

	Random	Panel	Plates
MALE			
SOV	1.000	0.552	0.704
HOV-2	1.000	0.593	0.733
HOV-3+	1.000	1.187	1.096
FEMALE			
SOV	1.000	1.001	1.013
HOV-2	1.000	1.003	0.940
HOV-3+	1.000	0.987	1.098

As shown in Figure 12.8 on page 157, 78.5% of female Avoiders who traveled in a shoulder period also traveled with another person (plum plus blue) compared to 37.5% of males. The null hypothesis that mode choice given shoulder period travel is independent of gender is rejected at the 10% level ($P < 0.001$; with Yates' correction, $P = 0.002$). Figure 12.8 also demonstrates that 49.9% of female Avoiders who traveled in a shoulder period also used a tollway (blue plus aqua) compared to 22.6% of males. The null hypothesis that route choice given shoulder period travel is independent of gender is rejected at the 10% level ($P = 0.018$; with Yates' correction, $P = 0.036$). This analysis of Avoider choice behavior indicates that among Avoiders traveling in shoulder periods, women are more likely than men to: a) be sharing a ride, and b) be using a tollway.

In particular, female Avoiders are more likely than male Avoiders to combine ridesharing and shoulder period travel. This author offers the purely speculative notion that for a given choice set, more so than for men, the choices that women make are shaped by their lifestyle or household responsibilities. Men are perhaps more likely to find that compared to the Shift alternative (for example), the incremental benefit (in terms of travel time savings) of combining ridesharing and shoulder period (i.e., of choosing the Carpool & Shift alternative) to be insufficient to compensate for combined burden of what may amount to “giving up” both the convenience of solo travel and the convenience of peak period travel.

Route Choice

Table 12.1 on page 140 shows that 33.3%¹⁴ of Shifters versus 41.2% of Avoiders used a tollway for the most recent trip. The null hypothesis that route choice and choice set (Shifters versus Avoiders) are independent is rejected at the 10% level ($P = 0.032$; with Yates' correction, $P = 0.039$). Among men, the finding is the same ($P = 0.057$), but among women the null hypothesis is *not* rejected at the 10% level ($P = 0.956$) with

¹⁴ From Table 12.1, $25.7 + 7.6 = 33.3\%$.

46.3% of female Time Shifters versus 46.7% of female choosing a tollway. These gender-specific comparisons between Shifters and Avoiders are shown in Figure 12.9, where the pertinent figure shown in blue is the proportion that used a tollway, regardless of how tollway was used, and the rest of the colors represent usage of considered free route alternatives.

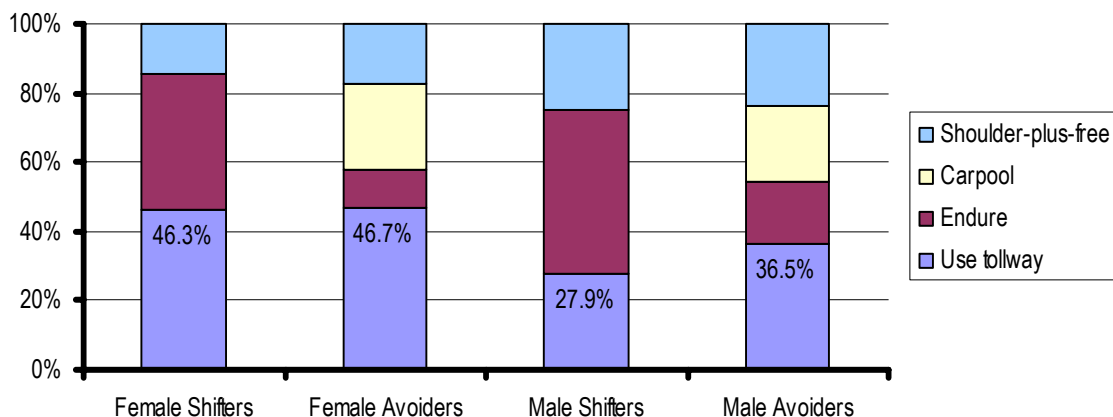


Figure 12.9 Shifters vs. avoiders, proportion choosing tollway alternatives

The above route choice analysis, which compares Shifters and Avoiders, indicates that route choice may be conditional on choice set. Previously, Carpoolers and Avoiders were compared with respect to route choice in Figure 12.5 on page 153, and the null hypothesis that route choice and choice set are independent was *not* rejected at the 10% level. The next analysis seeks further insight by comparing route choice for Carpoolers and Shifters.

Carpoolers vs. Shifters

Carpoolers have a four-alternative choice set, as do Shifters. They are similar only in that it is assumed that both consider Endure and Pay to be feasible alternatives.

Route Choice

From Table 12.1, 36.2%¹⁵ of Carpoolers and 33.3% of Shifters used a tollway for their recent trip. The null hypothesis that route choice and choice set (Carpoolers versus Shifters) is independent is not rejected at the 10% level ($P = 0.618$). Among men, the difference in route choice between Carpoolers and Shifters is not significant at the 10% level ($P = 0.127$), with 39.4% of male Carpoolers versus 27.9% of male Shifters choosing a tollway. As shown in Figure 12.10, the *opposite* trend is observed among females with 31.5% of female Carpoolers versus 46.3% of female Shifters choosing a tollway. The apparent disparity reflects the previously noted potential for differences among market segments in terms of the role of gender as a predictor for choice behavior.

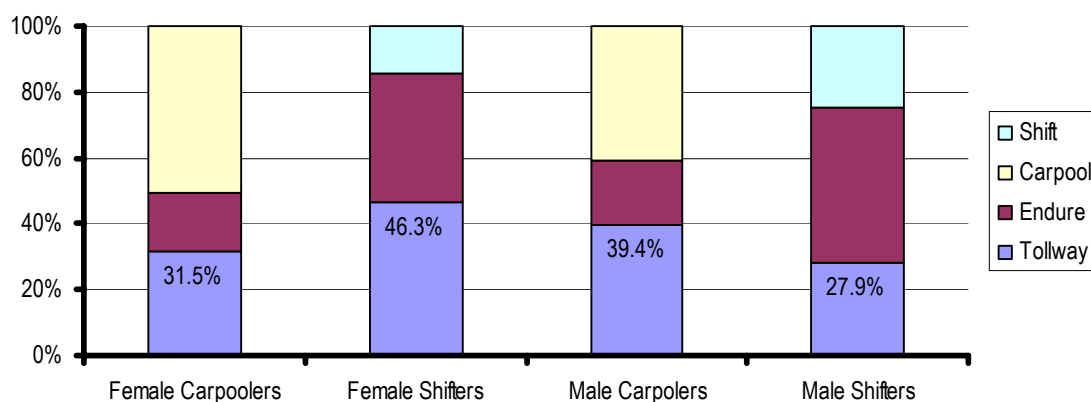


Figure 12.10 Carpoolers vs. shifters, proportion choosing tollway alternatives

Conclusion

The preceding analysis is a series of statistical comparisons designed to aid in interpreting revealed behaviors in the context of the proposed market segmentation. The

¹⁵ From Table 12.1, $4.0 + 32.2 = 36.2\%$ (difference due to rounding).

next step is to sort through potentially overlapping results and extract the principal findings. The following conclusions are supported by the statistical analysis and are expected to be reflected in the modeling work that follows.

1. Route choice is conditional on choice set. A choice model for value pricing should reflect the constraints of the considered choice set.
2. While gender seems to be an important predictor of route choice given choice set for Shifters, it is not clear that the same is true for other users.
3. The hypothesis that Carpoolers are more likely than Avoiders to share a ride because they do not also consider the option of traveling in a shoulder period is true for men but not for women.
4. Even though Avoiders may consider more alternatives to enduring congestion like ridesharing, it appears that Avoiders are as likely as Shifters to travel in a shoulder period, and that Avoiders are more likely to combine tollway and shoulder travel than to substitute tollway travel for shoulder period travel.
5. The hypothesis that Avoiders are more likely than Shifters to use a tollway is true for men but not for women.
6. Even though Avoiders also consider opportunities for shoulder period discounts, Avoiders are as likely as Carpoolers to use a tollway.
7. Among the four market segments, Endurers are least likely to use tollways. This is probably because they perceive only the full price of the toll.
8. More male Avoiders than female Avoiders favor Shift as a substitute for using tollways.
9. Women are more likely than men to combine shoulder period travel with sharing a ride and / or using a tollway.

In terms of the hypothesis that choice set is an important indicator for choice behavior, the preceding analysis is supportive. The *usual* approach for estimating a choice model is to rely on socioeconomic variables such as gender and income to explain observed differences in choice behavior. Statistical testing for choice as a function of the usual user attributes was presented earlier in Section 8 and suggests that persons with the same observed characteristics make different choices when it comes to value pricing. The statistical testing of choice as a function of choice set presented in this section, gives this author reason to believe that the reason for this is that the choice sets are different and that people with different choice sets make different choices when it comes to value pricing, perhaps due to differences in taste for the attributes of the alternatives. This is ultimately confirmed in the choice modeling portion of the work, which is described in the next two sections.

13 GENERIC MODEL ESTIMATION

This dissertation assumes that there are four types of travelers, where each type chooses from a different choice set. In Section 11, the choice set for each sampled individual was estimated empirically and the sample was divided into four groups. Most recently in Section 12, it was shown that route choice is conditional on choice set, and that travelers who consider all objectively available alternatives are more likely than others to have used a tollway for their most recent trip. It was also suggested that gender may not be universally associated with determining choice for a given choice set.

The modeling work described here and in the following section employs the theory of maximum likelihood estimation to sort through the potentially confounding effects of choice set and other user attributes on the choice probabilities. In this section, a model of multidimensional choice is tested using the joint logit model. The logit model is a multivariate technique that is commonly used for testing the determinants of choice behavior. (See Section 4 for a review of travel behavior models.) By allowing for potentially important variables to be simultaneously controlled, the logit model is a more powerful statistical method for answering the questions raised in this dissertation than the method of cross-tabulation featured in earlier descriptive analyses.

The primary goal of this section is to develop a satisfactory descriptive model estimated on the overall sample (i.e., the pooled sample). This is referred to herein as the ‘generic’ choice model because it does not distinguish between the four groups. As the first empirical model of mode, route, and time choice, this model is a tool that can be used to estimate traveler response to policy changes in the SR-91 corridor, and perhaps to predict traveler response to proposed value pricing projects elsewhere in California. (See Section 15 for a discussion of potential applications.)

In general, a model is satisfactory if it fits the data, is reasonable, and can be validated. In addition, it must satisfy the stated purpose. For this dissertation, the purpose of the

generic model is to provide an appropriate basis for testing the null hypothesis that there are variations of taste parameters among the four groups. For example, value of time may be distributed differently among Endurers than among Shifters, particularly with respect user attributes like gender and household income. Segment-specific characteristics are examined later in Section 14.

Model Variables

As previously defined, the universal choice set M consists of eight multidimensional travel alternatives listed in Table 13.1.

Table 13.1 Eight Travel Alternatives in the Universal Choice Set

$j =$	Alternative	Mode: Rideshare vs. Solo	Time: Shoulder vs. Peak	Route: Tollway vs. Free
1	Endure	Solo	Peak	Free
2	Carpool	Rideshare	Peak	Free
3	Pay	Solo	Peak	Tollway
4	Carpool & Pay	Rideshare	Peak	Tollway
5	Shift	Solo	Shoulder	Free
6	Shift & Carpool	Rideshare	Shoulder	Free
7	Shift & Pay	Solo	Shoulder	Tollway
8	Shift & Carpool & Pay	Rideshare	Shoulder	Tollway

The independent variables for alternative j and decision maker n are given in Table 13.2 and Table 13.3. The earlier analysis in Section 8, plus the work of other researchers who have estimated models for SR-91, suggests that these may be sufficient for the

purpose of estimating an adequate descriptive model of multidimensional choice behavior.

Table 13.2 Attributes of the Alternative

$PCost_{jn}$	Per-person toll cost (in dollars) for alternative j and person n , given n 's origin and destination
$TTime_{jn}$	Model-estimated travel time (in minutes) for alternative j and person n , given n 's origin and destination

Table 13.3 Socioeconomic Attributes of the Traveler

$Male_n$	Male gender dummy variable; 1 if individual n is male, otherwise 0
$FMale_n$	Female gender dummy variable; 1 if individual n is female, otherwise 0
$MidAge_n$	Age dummy variable; 1 if individual n is age 30 – 49 years, otherwise 0
$Degree_n$	Education dummy variable; 1 if individual n has a college degree, otherwise 0
$HHChild_n$	Household dummy variable; 1 if individual n has a child at home, otherwise 0
$Income_n$	Individual n 's annual household pre-tax income for 1998 divided by \$10,000, calculated as the mid-point of the income interval (except coded as 0.9 for the category < \$10,000 and 12.0 for the category \geq \$100,000)

A set of dimensional-specific dummy variables is defined in Table 13.4. These dummy variables are used in the model specification to assign a given variable to a particular subset of alternatives. For all tollway alternatives, $Toll_j = 1$ and for all free alternatives, $Free_j = 1$. With two mutually exclusive attributes, it is generally not necessary to define

a unique dummy variable for each one, though there is no harm in doing so and in the current specification it is shown to be convenient.

Table 13.4 Dimensional-Specific Dummy Variables

$Solo_j$	Solo mode dummy; 1 if alternative j has mode = solo, otherwise 0
$RShare_j$	Rideshare mode dummy; 1 if alternative j has mode = rideshare, otherwise 0
$Peak_j$	Peak time dummy; 1 if alternative j has time = peak, otherwise 0
$Shldr_j$	Shoulder time dummy; 1 if alternative j has time = shoulder, otherwise 0
$Free_j$	Free route dummy; 1 if alternative j has route = free, otherwise 0
$Toll_j$	Toll route dummy; 1 if alternative j has route = tollway, otherwise 0

Omitting for now all socioeconomic attributes shown in Table 13.3 from the function, the general form of the disutility expression given by:

$$U_{jn} = \delta_1 * RShare_j * Peak_j + \delta_2 * Solo_j * Shldr_j + \delta_3 * RShare_j * Shldr_j + \beta_1 * PCost_{jn} + \beta_2 * TTime_{jn} + \varepsilon_{jn}, \quad \forall j = 1, \dots, 8 \quad (13.1)$$

where:

$[\delta_1, \dots, \delta_S, \beta_1, \dots, \beta_T]$ = the vector of $S + T$ unknown parameters β , and

ε_{jn} = the unobservable component of disutility.

For each of the eight alternatives listed in Table 13.1, the expression $U_{jn} - \varepsilon_{jn}$ reduces as shown in Table 13.5. Here, it can be more clearly seen that the δ 's are the alternative-

specific constants. These constants are interpreted as being reflective of the mean of the difference $\varepsilon_j - \varepsilon_i$, which is the difference in the disutility of alternative j from that of alternative i when all other variables in the model are equal. The specification of the δ 's reflects an a priori assumption regarding relative preference, which is made explicit in the discussion that follows.

Table 13.5 Systematic Disutility Expressions, Minimum Generic Model

$j =$	Alternative	$U_{jn} - \varepsilon_{jn} =$
1	Endure	$\beta_2 * TTime_{1n}$
2	Carpool	$\delta_1 * RShare_2 * Peak_2 + \beta_2 * TTime_{2n}$
3	Pay	$\beta_1 * PCost_{3n} + \beta_2 * TTime_{3n}$
4	Carpool & Pay	$\delta_1 * RShare_4 * Peak_4 + \beta_1 * PCost_{4n} + \beta_2 * TTime_{4n}$
5	Shift	$\delta_2 * Solo_5 * Shldr_5 + \beta_2 * TTime_{5n}$
6	Shift & Carpool	$\delta_3 * RShare_6 * Shldr_6 + \beta_2 * TTime_{6n}$
7	Shift & Pay	$\delta_2 * Solo_7 * Shldr_7 + \beta_1 * PCost_{7n} + \beta_2 * TTime_{7n}$
8	Shift & Carpool & Pay	$\delta_3 * RShare_8 * Shldr_8 + \beta_1 * PCost_{8n} + \beta_2 * TTime_{8n}$

The cost term $\beta_1 * PCost_j$ represents the mean of the difference in error terms, $\varepsilon_j - \varepsilon_i$, whenever any tollway alternative $j = 3, 4, 7, 8$ and the corresponding free alternative $i = j - 2$ are compared. One example is the Carpool & Pay alternative ($j = 4$) and the Carpool alternative ($j = 2$), which are given the same alternative-specific constant (δ_1). When the travel times for the two alternatives are equal (i.e., when $TTime_4 = TTime_2$), the cost term $\beta_1 * PCost_4$ represents the mean of the difference in error terms $\varepsilon_4 - \varepsilon_2$.

Together, the disutility expressions in Table 13.5 represent the ‘minimum’ generic model specification, which includes only travel time, cost, and the alternative-specific constants. The final ‘preferred’ specification is achieved by adding socioeconomic variables from Table 13.3 and systematically evaluating each variation of the model to identify the one with the most explanatory power.

Behavioral Expectations

Rather than conduct a complete enumeration, the model development was predicated on a series of a priori expectations. The first set of expectations pertains to the alternative-specific constants. One of these expectations is that the relative values of the alternative-specific constants are such that when all else is equal, the probability of choosing Endure is greater than the probability of choosing Shift. This is referred to as expectation E1.1, which is based on the understanding that most commuters have a greater preference for travel during peak times than for travel during shoulder times. Expectation E1.2 is that the relative values of the alternative-specific constants are such that when all else is equal, the probability of choosing Shift is greater than the probability of choosing Shift & Carpool. This says that when traveling in the shoulder period commuters have a greater preference for solo travel than rideshare travel. These and other expectations regarding alternative-specific constants are given in Table 13.6.

Table 13.6 Expectations for Alternative-Specific Constants

Expectation	When all else is equal the probability of choosing...	is	...the probability of choosing	Thus,
E1.1	Endure	>	Shift.	$\delta_2 < 0$
E1.2	Shift & Carpool	<	Shift.	$\delta_3 < \delta_2 < 0$
E1.3	Endure	>	Carpool.	$\delta_1 < 0$
E1.4	Shift & Carpool	<	Carpool.	$\delta_3 < \delta_2 < 0$

A second set of expectations in Table 13.7 pertains to the time and cost attributes of the alternatives. The coefficients should be negative because, when all else is equal, travelers prefer lower time and cost alternatives. This is self-evident and requires no further explanation.

Table 13.7 Expectations for Generic Attributes of the Alternatives

Expectation	The coefficient of	is	..such that when all else is equal...	Thus,
E2.1	$PCost_{jn}$	< 0	Travelers prefer lower cost alternatives.	$\beta_1 < 0$
E2.2	$TTime_{jn}$	< 0	Travelers prefer lower travel time alternatives.	$\beta_2 < 0$

A third set of expectations relates user attributes to choice behavior. The expectation that increasing income increases the probability of choosing a tollway alternative (e.g., $j = 3,4,7,8$), is reflected in the model by interacting $Toll_j$ and $Income_n$, as shown in Table 13.8. With respect to this and the other expectations listed in Table 13.8,

statistical evidence from the cross-tabulations in Section 8 is largely inconclusive. The multivariate approach used in this section will yield a better statistical answer regarding the extent to which the attributes listed here affect the choice probabilities. Ultimately, the analysis in Section 14 investigates the possibility that one or more is segment specific.

Table 13.8 Expectations for User Attributes

Expectation	The coefficient of	is	...such that
E3.1	$Toll_j * Income_n$	> 0	increasing income increases the probability of choosing a tollway alternative.
E3.2	$Toll_j * Male_n$	< 0	a male is less likely than a female to choose a tollway alternative.
E3.3	$Toll_j * MidAge_n$	> 0	a person age 30 – 49 is more likely than others to choose a tollway alternative.
E3.4	$Toll_j * Degree_n$	> 0	a person with a college degree is more likely than others to choose a tollway alternative.
E3.5	$RShare_j * HHChild_n$	> 0	a person with one or more children at home is more likely than others to choose a rideshare alternative.

Parameter Estimation

In the model development process, five variations on the generic model are estimated using the maximum likelihood method. The five models are shown in Table 13.10. For this work, the statistical analysis software known as Stata, version 7 was used. The data on which the model is estimated is from 797 surveyed commuters who gave full survey responses including the origin, destination, mode, route, and time of their most recent study period trip as well as their gender, age, household income, household type, and education. (Refer to Section 7 for a description of the sampling procedures.) The set of $N = 797$ observations is the Calibration Set. The remaining 142¹⁶ surveyed commuters

¹⁶ $797 + 142 = 939$ individuals in the study sample.

who gave full descriptions of their most recent peak trip but failed to report needed socioeconomic data are not used in model estimation. The Discard Set (N = 142) has some value in terms of serving as a control group and is used later for model validation.

As before, observations from the two choice-based subsamples are weighted relative to the random dial sample in order to reduce the bias from non-random sampling. The weight for individual n is equal to the ratio of the random dial share of people making the same mode-route choice as individual n to the share of that choice in the choice-based subsample. The set of weights, or expansion factors, previously presented in Table 7.5 on page 76 was originally computed for the full study sample (N = 939). A revised set of weights for the Calibration Set (N = 797) is given in Table 13.9.

Table 13.9 Expansion Factors for the Calibration Set (N = 797)

	Random	Panel	Plates
MALE			
Rideshare-Shoulder	1.000	2.565	1.156
Rideshare-Peak	1.000	0.463	0.566
Solo-Shoulder	1.000	1.503	1.195
Solo-Peak	1.000	1.090	1.099
FEMALE			
Rideshare-Shoulder	1.000	2.602	2.404
Rideshare-Peak	1.000	0.743	0.757
Solo-Shoulder	1.000	0.818	1.888
Solo-Peak	1.000	1.078	0.939

The model is estimated by maximizing the weighted log-likelihood function:

$$L = \sum_{n=1}^N \sum_{j=1}^{J_n} w_n y_{nj} \ln(P_{nj}) \quad (13.2)$$

where

N = the sample size

J_n = the number of alternatives available to sample member n

$y_{nj} = 1$ if individual n chooses alternative j , otherwise 0

w_n = the weight, or expansion factor, applying to individual n , and

P_{nj} = the probability that individual n chooses alternative j , which is

computed with the familiar joint logit model (see Section 5).

For the test of taste variations among choice set groups unweighted estimation is also used (see Section 14).

For each version of the generic model, G.1 through G.5, the estimates of the coefficients are given along with the z statistic, shown in parentheses.¹⁷ Coefficients that are not

¹⁷ For maximum likelihood estimation, the Stata program output includes for each independent variable, a z statistic, which is equal to the coefficient divided by the standard error, and is distributed normally. When N is large, it makes little difference whether a t-distribution or a normal distribution is used. Some programs label this statistic a t-test. The Stata program correctly labels it a z-test, which may be interpreted in the same way as a t-test. If the z statistic is greater than 1.96, this means that the coefficient is at least twice the size of its standard error, which indicates that the coefficient is statistically significant at the 5% level or better.

statistically significant at the 10% level are flagged with an asterisk. A detailed description of the model development process follows. The discussion features a series of likelihood ratio tests (defined below) to aid in discerning the preferred model specification.

Let $\hat{\beta} = [\delta_1, \dots, \delta_S, \beta_1, \dots, \beta_T]'$ be the estimate for the vector of $S + T$ unknown parameters, which expresses both the relative magnitudes of the constants and the importance that decision makers place on observed attributes. In Table 13.10, each column represents a different vector of estimated model coefficients ($\hat{\beta}_{G.1}, \dots, \hat{\beta}_{G.5}$).¹⁸ Model G.1 is the minimum model where the only variables in the model are travel time ($TTime_n$), cost ($PCost_n$), and the alternative-specific constants (the δ 's). As shown, Model G.1 supports initial expectations regarding the relative magnitudes of the alternative-specific constants ($\delta_3 < \delta_2 < 0$ and $\delta_3 < \delta_1 < 0$, see expectations E.1 – E.4). Based on the magnitudes of the coefficients for $PCost_n$ and $TTime_n$, Model G.1 estimates the marginal rate of substitution between time and money to be \$10.61 per

¹⁸ As before, the observations in the two choice-based subsamples are weighted according to observed mode-time shares. For the model estimation work, the expansion factors are recalculated to adjust for the smaller sample with $N = 797$ instead of $N = 939$.

Table 13.10 Estimation Results for the Generic Models G.1 – G.5 (N = 797)

Variable	Coef.	G.1	G.2	G.3	G.4	G.5
$RShare_j * Peak_j$	δ_1	-2.581 (-12.33)	-2.848 (-12.77)	-2.949 (-13.04)	-2.947 (-13.04)	-2.935 (-13.01)
$Solo_j * Shldr_j$	δ_2	-2.392 (-12.20)	-2.400 (-11.99)	-2.455 (-12.21)	-2.453 (-12.22)	-2.440 (-12.17)
$RShare_j * Shldr_j$	δ_3	-3.867 (-14.36)	-4.126 (-14.62)	-4.262 (-14.88)	-4.260 (-14.88)	-4.241 (-14.86)
$PCost_{jn}$	β_1	-0.407 (-10.60)	-0.367 (-5.78)	-0.509 (-6.72)	-0.508 (-6.71)	-0.486 (-6.59)
$TTime_{jn}$	β_2	-0.072 (-6.69)	-0.073 (-6.65)	-0.074 (-6.72)	-0.074 (-6.72)	-0.074 (-6.73)
$Toll_j * Male_n$	β_5		-0.591 (-3.78)	-0.684 (-4.30)	-0.685 (-4.30)	-0.670 (-4.22)
$Toll_j * MidAge_n$	β_6		+0.306 (2.06)	+0.192 (1.26) *	+0.193 (1.27) *	
$Toll_j * Degree_n$	β_7		+0.234 (1.54) *	+0.057 (0.35) *		
$RShare_j * FMale_n * HHChild_n$	β_8		+1.287 (6.38)	+1.257 (6.21)	+1.256 (6.21)	+1.268 (6.27)
$Toll_j * Income_n$	β_9			+0.078 (3.45)	+0.080 (3.76)	+0.087 (4.17)
VOT (\$ per hr): $\beta_2/\beta_1 * 60 =$		\$ 10.61	\$ 11.93	\$8.72	\$ 8.74	\$ 9.14
Log-likelihood, $L(\hat{\beta})$		-1366.2	-1333.5	-1327.5	-1327.5	-1330.5
Pseudo R^2 ¹⁹		0.041	0.064	0.068	0.068	0.073

* Coefficient not significant at the 10% level.

¹⁹ Pseudo $R^2 = L(\hat{\beta})/L(0)$ where $L(0)$ is the log-likelihood value if all β_i are zero and all δ_s are non-zero.

hour. This value has the expected order of magnitude for value of time²⁰ and helps confirm that Model G.1 is a good starting point for model development.

Model G.2 adds to Model G.1 by incorporating socioeconomic attributes assumed to be associated with choice behavior, but not income.²¹ The parameters and the estimates of the coefficients for Model G.2 are given in Table 13.10 on page 174. It can be seen that gender, age, and education appear in Model G.2, respectively with β_5 , β_6 , and β_7 , and as originally specified in expectations E3.2 – E3.4 on page 170. With respect to mode choice, the household variable $RShare_j * HHChild_n$ is modified from the original expectation E3.5 because a preliminary analysis revealed a large standard error relative to the estimate of the coefficient. At 149% of the estimate, the standard error for $RShare_j * HHChild_n$ is considered large and the coefficient is not significant at the 10% level. The analysis in Section 11 suggests a stronger connection between household structure and ridesharing for women than for men, and it is appropriate that Model G.2 explore the likely possibility that having a child at home is an important mode choice predictor only for women. This is accomplished by interacting $RShare_j$, $HHChild_n$, and $FMale_n$, as shown in the row associated with β_8 .

The likelihood ratio test (LR test) is used to compare Model G.2 with Model G.1. The LR test procedure compares two candidate models: the full model and the reduced model. Model G.2 is the full model because it has more parameters, and Model G.1 is the reduced model. This comparison is a test of the hypothesis that the coefficients on the variables found in Model G.2 but not in Model G.1 are all zero (i.e.,

$$H_0 : \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0).$$

²⁰ The models developed by Yan et al. (41) show implied values of time for Orange County commuters in the range of \$13 to \$16 per hour.

²¹ Income enters in a subsequent version of the model (Model G.3).

Let L_0 and L_1 be the log-likelihood values associated with the full and reduced models respectively. The LR test statistic (χ^2), is $\chi^2 = -2(L_1 - L_0)$ with $d_0 - d_1$ degrees of freedom, where d_0 and d_1 are the degrees of freedom associated with the full and reduced models. If χ^2 is larger than a chi-square percentile corresponding to the chosen confidence level and $d_0 - d_1$ degrees of freedom, denoted $\chi_c^2 = \chi_{(1-\alpha; d_0-d_1)}^2$ then H_0 is rejected (59, p. 589).

In the case of Model G.2 versus Model G.1 and $\alpha = 0.10$, the computed value of the test statistic, $\chi^2 = 65.58$, is larger than the critical value, $\chi_{(0.90;4)}^2 = 7.78$. Based on this result with $P < 0.001$, $H_0 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$ is rejected at the 10% level in favor of the alternative hypothesis, H_a : not all β_i in H_0 equal zero. It is concluded that at least one of the socioeconomic variables is important to the choice and thus, Model G.1 appears to be the poorer of the two models. While Model G.2 may be favorable compared to Model G.1, additional hypothesis testing regarding individual socioeconomic variables is required, as discussed below.

The full series of LR tests used in developing the generic model are summarized in Table 13.11. Each LR test is a test between a pair of candidate generic models found in Table 13.10. The LR tests are numbered. For each test, the numbering identifies the full model first and the reduced model second. Once income is also introduced in Model G.3, it can be seen that subsequent LR tests systematically target individual variables not shown to be significant at the 10% level. Essentially, Table 13.10 presents each permutation in the process of arriving at the preferred specification for the generic model, and Table 13.11 documents the associated statistical testing procedures used to determine whether to keep or drop particular variables.

Table 13.11 LR Tests Used in Developing the Generic Model

Test No.	H_0	χ^2	P-value	Reject H_0 at $\alpha = 0.10$
G2.G1	$\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$	65.6	< 0.001	Yes
G3.G2	$\beta_9 = 0$	12.0	0.001	Yes
G3.G4	$\beta_7 = 0$	0.1	0.724	No
G4.G5	$\beta_6 = 0$	5.9	0.015	Yes

Model G.3 adds to Model G.2 by also incorporating income ($\beta_9 * Toll_j * Income_n$). Note that in Model G.2 the education variable $\beta_7 * Toll_j * Degree_n$ is not significant at the 10% level. The null hypothesis $H_0 : \beta_7 = 0$ will be tested in the next version of the model. As shown in Table 13.10, $\beta_9 > 0$ as expected (see expectation E3.1). The second LR test, test number G3.G2 in Table 13.11, compares Model G.3 against Model G.2. The result of the test ($\chi^2 = 12.0$, $P = 0.001$; reject $H_0 : \beta_9 = 0$ at the 10% level) indicates that income is important to the choice of tollway alternatives. Relative to Model G.3, it appears that Model G.2 is the poorer model.

In Model G.3, the estimate for the education variable $\beta_7 * Toll_j * Degree_n$ is not significant at the 10% level.²² Model G.4 is Model G.3 without the education variable. The third LR test, number G3.G4 in Table 13.11, is a test of the null hypothesis $H_0 : \beta_7 = 0$. The result of this test ($\chi^2 = 0.1$, $P = 0.724$; fail to reject $H_0 : \beta_7 = 0$ at the 10% level) suggests that education is not an important predictor in the choice of tollway alternatives. Relative to Model G.4, it appears that Model G.3 is the poorer model.

²² Relative to the estimated coefficient, the standard error is high (282.5% of the estimate).

In Model G.4, the estimate for the age variable $\beta_6 * Toll_j * MidAge_n$ is not significant at the 10% level. Model G.5 is Model G.4 without the age variable. LR test G4.G5 *rejects* the hypothesis $H_0 : \beta_6 = 0$ at the 10% level ($\chi^2 = 5.9$, $P = 0.015$). Thus, it may be appropriate to keep the age variable in the model even though the standard error is relatively high at 78.7% of the estimate. The question of whether or not age is associated with the tollway choice across all four choice set groups is investigated later in Section 14. At this point, Model G.4 is the preferred model specification and it is appropriate that it be examined more closely.

The systematic disutilities given by Model G.4 are written out in Table 13.12. For ease of presentation, let $\Psi_n = -0.685 * Male_n + 0.193 * MidAge_n$. By inspection of Ψ_n it can be seen that women age 30 – 49 years are more likely than other users to choose tollway alternatives. The Ψ_n term at the end of the disutility expressions for alternatives $j = 3, 4, 7, 8$ effectively acts as a user-specific adjustment to the alternative-specific constant and is one way that differences in taste (i.e., preferences) for tollway alternatives among individual decision makers are represented. For women age 30 – 49 years, $\Psi_n = +0.193$. For women younger than 30 or older than 49 years, $\Psi_n = 0$. For men age 30 – 49, $\Psi_n = -0.492$ and for men younger than 30 or older than 49 years, $\Psi_n = -0.685$.

Table 13.12 Systematic Disutilities of the Alternatives, Preferred Generic Model

$j =$	$U_{jn} - \varepsilon_{jn} =$
1	$-0.074 * TTime_1$
2	$-2.947 - 0.074 * TTime_2 + 1.256 * FMale_n * HHChild_n$
3	$-0.508 * PCost_3 - 0.074 * TTime_3 + 0.080 * Income_n + \Psi_n$
4	$-2.947 - 0.508 * PCost_4 - 0.074 * TTime_4 + 0.080 * Income_n + 1.256 * FMale_n * HHChild_n + \Psi_n$

5	$-2.453 - 0.074 * TTime_5$
6	$-4.260 - 0.074 * TTime_6 + 1.256 * FMale_n * HHChild_n$
7	$-2.453 - 0.508 * PCost_7 - 0.074 * TTime_7 + 0.080 * Income_n + \Psi_n$
8	$-4.260 - 0.508 * PCost_8 - 0.074 * TTime_8 + 0.080 * Income_n + 1.256 * FMale_n * HHChild_n + \Psi_n$

Using the method of sample enumeration, the disutility functions associated with the preferred generic model, as shown in Table 13.12, are used to predict the choice shares for the sample on which the model was estimated. The sample on which the model was estimated is referred to herein as the Calibration Sample (N = 797). The predicted shares are given along with the observed choice shares in Table 13.13, and are reported separately for men and women in Table 13.14 on page 181. As shown in Table 13.13, Model G.4 predicts that 19.0% of the Calibration sample will choose the Pay alternative compared to 20.4% who actually did choose the Pay alternative for their most recent Monday through Thursday trip. As shown in Table 13.15 on page 182, the choice shares predicted by the other four models (Models G.1, G.2, G.3, and G.5) are similar to the choice shares predicted by Model G.4.

Table 13.13 Observed vs. Predicted Choice Shares, Preferred Generic Model (Model G.4)

$j =$		Observed Unweighted	Observed Weighted ²³	Predicted Model G.4
1	Endure	36.9%	37.8%	39.9%
2	Carpool	12.5%	9.9%	9.0%

²³ As before, when men and women are combined the observations are weighted relative to observed mode-time-gender shares.

$j =$		Observed Unweighted	Observed Weighted ²³	Predicted Model G.4
3	Pay	19.7%	20.4%	19.0%
4	Carpool & Pay	10.7%	7.9%	8.2%
5	Shift	11.9%	13.0%	11.7%
6	Shift & Carpool	2.8%	4.4%	3.3%
7	Shift & Pay	3.5%	4.1%	5.8%
8	Shift & Carpool & Pay	2.0%	2.5%	3.1%
	TOTAL	100%	100%	100%

Table 13.14 Observed vs. Predicted Choice Shares, Preferred Generic Model (Model G.4)

		Men		Women	
$j =$		Observed Weighted	Predicted Model G.4	Observed Weighted	Predicted Model G.4
1	Endure	42.8%	44.7%	29.0%	29.5%
2	Carpool	6.6%	8.1%	15.2%	10.9%
3	Pay	19.5%	17.8%	22.3%	21.5%
4	Carpool & Pay	5.9%	5.5%	11.3%	13.9%
5	Shift	17.3%	13.3%	5.7%	8.4%
6	Shift & Carpool	2.5%	3.0%	7.2%	4.0%
7	Shift & Pay	4.2%	5.5%	4.1%	6.5%
8	Shift & Carpool & Pay	1.2%	2.1%	5.2%	5.3%
	TOTAL	100%	100%	100%	100%

Table 13.15 Choice Shares as Predicted by Model G.1 through Model G.5

$j =$		Model G.1	Model G.2	Model G.3	Preferred Model G.4	Model G.5
1	Endure	39.4%	39.0%	39.6%	39.9%	39.5%
2	Carpool	9.8%	9.7%	9.0%	9.0%	9.2%
3	Pay	19.6%	19.6%	19.0%	19.0%	19.0%
4	Carpool & Pay	7.2%	7.4%	8.2%	8.2%	8.0%
5	Shift	11.8%	12.0%	11.7%	11.7%	11.9%
6	Shift & Carpool	3.7%	3.7%	3.3%	3.3%	3.4%
7	Shift & Pay	5.8%	5.6%	5.8%	5.8%	5.8%
8	Shift & Carpool & Pay	2.7%	2.8%	3.1%	3.1%	3.0%
	TOTAL	100%	100%	100%	100%	100%

Validating the Generic Model

As previously indicated, 142 observations were not used in estimating the generic model only because these subjects failed to report key socioeconomic information, like age and household income. As a subset of the study sample, these observations have limited use in model validation. Due to the missing information, the Discard Set is not suitable for testing the preferred generic model Model G.4, but can be used to test the minimum generic Model, Model G.1. The shares predicted by Model G.1 using sample enumeration for the Discard Set are given in Table 13.16 alongside the *unweighted* observed choice shares. As shown, Model G.1 predicts that 19.6% of the Discard Set will choose the Pay alternative, compared to 21.8% who actually did choose the Pay alternative for the most recent trip. Like the Calibration Sample, the Discard Set

includes observations from the two choice based subsamples. Though it is preferable to adjust the observed choice shares to account for non random sampling in the Discard Set, in this case it is not feasible because the random dial subsample contains zero Rideshare-Shoulder observations. With zero observations, it is not possible to ‘factor’ the few Rideshare-Shoulder observations contained in the two choice-based subsamples to match the ‘zero share’ observed in the random dial subsample. Nonetheless, it appears that Model G.1 predicts the choice shares for the Discard Set about as well as it predicts the choice shares for the Calibration Sample.

Table 13.16 Observed vs. Predicted Choice Shares, Minimum Generic Model (Model G.1)

		Discard Set		Calibration Sample	
$j =$	Alternative	Observed Unweighted	Predicted Model G.1	Observed Unweighted	Predicted Model G.1
1	Endure	40.1%	39.7%	36.9%	39.4%
2	Carpool	14.8%	9.6%	12.5%	9.8%
3	Pay	21.8%	19.6%	19.7%	19.6%
4	Carpool & Pay	8.5%	7.1%	10.7%	7.2%
5	Shift	8.5%	11.9%	11.9%	11.8%
6	Shift & Carpool	2.1%	3.6%	2.8%	3.7%
7	Shift & Pay	4.2%	5.8%	3.5%	5.8%
8	Shift & Carpool & Pay	0%	2.7%	2.0%	2.7%
	TOTAL	100%	100%	100%	100%

Interpreting the Preferred Generic Model, Model G.4

Model G.4 appears to be a good descriptive model for the overall population. Model G.4 is consistent with all but one of the expectations outlined at the start (see Table 13.6 through Table 13.8). Only the expectation that individual n 's education has an important effect of the probability that n chooses a tollway alternative is unsupported in the multivariate analysis. Given that there is no statistical evidence in Section 8 to suggest an association between having a college degree and tollway use, this was never a particularly strong expectation.²⁴

Model G.4 is useful in that it describes relative preference between Carpool and Shift, for which no *a priori* assumption was formed. The alternative-specific constants indicate that when travel times are equal, the disutility associated with the Carpool alternative is greater than the disutility associated with the Shift alternative ($\delta_1 = -2.947 < \delta_2 = -2.453$). This suggests that for the average user the inconvenience of ridesharing is a greater burden than the inconvenience of traveling during shoulder periods.

Model G.4 also reveals information about values of time and the effects of socioeconomic attributes on the choice probabilities. According to the Model G.4, a female commuter with an annual household income of \$80,000 who faces a \$3.00 peak period toll will be indifferent between Endure ($j = 1$) and Pay ($j = 3$) when Pay saves 9.3 minutes compared to Endure. If ${}^i_j \Delta TTime$ represents the difference in travel times that results in $U_{in} - \varepsilon_{in} = U_{jn} - \varepsilon_{jn}$, then it can be said that for females age 30 – 49 years

²⁴ It was nonetheless included, partly because other researchers had identified education as an important predictor variable (see for example 41).

with a household income of \$80,000, ${}^3_1\Delta TTime = 9.3$ minutes²⁵ and that the value of time (VOT) for this socioeconomic group is \$19.35 per hour. VOT estimates for other socioeconomic groups are shown in Table 13.17.

Table 13.17 Preferred Generic Model G.4: $\Delta TTime$ and VOT Estimates (Assuming a \$3.00 Peak Toll)

	Female, age 30 – 49	Female, age < 30 or > 49	Male, age 30 – 49
\$80,000	${}^3_1\Delta TTime = 9.3$ minutes (\$19.35 / hr)	${}^3_1\Delta TTime = 11.9$ minutes (\$15.13 / hr)	${}^3_1\Delta TTime = 18.6$ minutes (\$9.68 / hr)
\$40,000	${}^3_1\Delta TTime = 13.7$ minutes (\$13.14 / hr)	${}^3_1\Delta TTime = 16.3$ minutes (\$11.04 / hr)	${}^3_1\Delta TTime = 22.9$ minutes (\$7.86 / hr)

Model G.4 is hypothesized to be an appropriate model for testing the null hypothesis that there are variations of taste parameters among the four choice set segments, and that the value of time is related to choice set. This dissertation investigates the notion that the effects of attributes such as income on the choice probabilities, are choice set specific. It is hypothesized, for example, that for some segments, the generic model overestimates the effect of household income on the probability of choosing the Pay alternative. The test of variations of taste parameters is accomplished in the next section by re-estimating the model on the pooled sample under the assumption of user-specific choice sets, and again for each segment individually.

²⁵ Set $U_1 - \varepsilon_1 = -0.074 * TTime_1$ equal to

$U_3 - \varepsilon_3 = -0.508 * \$3.00 - 0.074 * TTime_3 + 0.193 + 0.080 * 8 = -0.691 - 0.074 * TTime_3$, which reduces to

$U_3 - \varepsilon_3 = -0.691 - 0.074 * TTime_3$, and solve for $TTime_1 - TTime_3 = 0.691/0.074 = 9.3$ minutes.

14 MARKET SEGMENTATION

In the previous section, a multidimensional joint logit model was estimated under the usual assumption that each member of the population chooses from the universal choice set M . Here, it is assumed that each member of the population has one of four potential subsets of M as his or her considered choice set and that for any alternative not in the considered set, the choice probability is zero. As previously demonstrated in Section 10, the method of choice set formation used in this study is both simple and inexpensive. A successful demonstration of choice set as an indicator for choice behavior would establish choice set based market segmentation as a valuable and important tool with potential applications in equity analysis, predicting the demand for value pricing, and activity-based modeling.

In this section, the first task is to re-estimate the preferred generic model, Model G.4, under the condition of user-specific choice sets. The second task is to find out whether or not decision makers with different choice sets have different preferences for value pricing. This is accomplished by testing the hypothesis that the vector of coefficients is the same for the four choice set segments. Finally, the set of segment-specific models are examined to identify the specific coefficients to which differences in the vectors can be attributed.

As previously defined in Section 10, the four potential subsets of the universal choice M set are listed in Table 14.1 below, where $M_4 \equiv M$.

Table 14.1 Four Pre-defined Subsets of the Universal Choice Set

M_1	$\{Endure, Pay\}$
M_2	$\{Endure, Pay, Shift, Shift \& Pay\}$
M_3	$\{Endure, Carpool, Pay, Carpool \& Pay\}$
M_4	$\{Endure, Carpool, Pay, Carpool \& Pay, Shift, Shift \& Pay, Shift \& Carpool, Shift \& Carpool \& Pay\}$

Table 14.2 Four Segments of the Sample

Segment	Considered Choice Set	Segment Sample Size
Endurers	M_1	117
Shifters	M_2	363
Carpoolers	M_3	72
Avoiders	M_4	245

For each person in the Calibration Set ($N = 797$), the considered choice set was previously estimated (see Section 11). As shown in Table 14.2, the sample is divided into four segments such that within each segment all members have the same considered

choice set. The Shifter segment is the largest of the four groups and the Carpooler segment is the smallest. Assuming that there are taste variations to be found among the groups, it is not unlikely that in the generic model, the tastes of the Shifters dominate and the tastes of the Carpoolers are obscured.

Constraining the Generic Model

The preferred generic model is re-estimated on the pooled sample under the assumption of user-specific choice sets (i.e., $C_n = C'_n = M_r$). This is referred to herein as the *constrained* estimation, which is identified as Model G.4.C and is shown in the right side Table 14.3. The coefficients for Model G.4 originally presented in Table 13.10 on page 174 assume $C_n = M$ for all n and is referred to herein as the *unconstrained* estimation. The unconstrained estimation is now identified as Model G.4.U and appears again here in Table 14.3. As expected, the log-likelihood for the constrained estimation ($L = -1037.8$) is greater than the log-likelihood value for the unconstrained estimation ($L = -1327.5$). The former is used in the upcoming test of taste variations. In preparation for repeating the test of taste variations for the condition of unweighted maximum likelihood estimation, the constrained model is re-estimated without the expansion factors (see Table 13.9 and Equation 13.2) and the results are given in the final column of Table 14.3.

Table 14.3 Estimation Results, Preferred Generic Model, Unconstrained vs. Constrained vs. Unweighted

Variable	Coef.	Unconstrained $C_n = M$ Model G.4.U	Constrained $C_n = C'_n = M_r$ Model G.4.C	Constrained $C_n = C'_n = M_r$ Model G.4.C Unweighted
$RShare_j * Peak_j$	δ_1	- 2.947 (-13.04)	- 1.191 (-4.53)	- 0.825 (-3.20)
$Solo_j * Shldr_j$	δ_2	- 2.453 (-12.22)	- 2.221 (-9.65)	- 2.358 (-10.08)
$RShare_j * Shldr_j$	δ_3	- 4.260 (-14.88)	- 2.218 (-6.79)	- 2.477 (-7.37)
$PCost_{jn}$	β_1	- 0.508 (-6.71)	- 0.517 (-6.58)	- 0.570 (-7.32)
$TTime_{jn}$	β_2	- 0.074 (-6.72)	- 0.082 (-6.42)	- 0.084 (-6.48)
$Toll_j * Male_n$	β_5	- 0.685 (-4.30)	- 0.668 (-4.14)	- 0.622 (-3.89)
$Toll_j * MidAge_n$	β_6	+ 0.193 (1.27) *	+ 0.177 (1.16) *	+ 0.169 (1.11) *
$RShare_j * FMale_n * HHChild_n$	β_8	+ 1.256 (6.21)	+ 0.943 (2.95)	+ 0.683 (-2.15)
$Toll_j * Income_n$	β_9	+ 0.080 (3.76)	+ 0.076 (3.58)	+ 0.093 (4.32)
VOT (\$ per hr); $\beta_2 / \beta_1 * 60 =$		\$ 8.74	\$ 9.52	\$ 8.84
Log-likelihood (L)		- 1327.5	- 1037.8	- 1020.4

* Coefficient not significant at the 10% level

Some of the effects of constraining the estimation to each decision maker's choice set can be seen in the alternative-specific constants. Under the assumption of user specific choice sets, Avoiders are the only decision makers who consider the universal choice set, and are therefore the only decision makers for whom comparisons among the alternative specific constants is meaningful.

Whereas Model G.4.U supports the a priori expectation $\delta_2 > \delta_3$ (see expectation E1.2 in Table 13.6 on page 169), Model G.4.C does not. Rather, Model G.4.C indicates $\delta_2 \approx \delta_3$, which is interpreted to mean that when travel times are equal the average Avoider is largely *indifferent* between Shift and Carpool & Shift. In other words, among the subset of users who consider the universal choice set, it appears that for shoulder period travel, the incremental disutility of also sharing a ride is basically negligible.

Between the Carpool and Shift alternative, the constrained model suggests that when travel times are equal the average Avoider perceives less disutility associated with the Carpool alternative ($\delta_1 = -1.141 > \delta_2 = -2.232$). In the, unconstrained model (Model G.4.U), the opposite relationship is given ($\delta_1 = -2.947 < \delta_2 = -2.453$). Thus, it appears that the usual assumption that every decision maker chooses from the universal choice set has the effect of distorting, for those who actually consider the universal set, the order of the alternative-specific constants.

Hypothesis of Equal Vectors

The models that have been estimated thus far incorporate various socioeconomic variables, which may potentially account for different people having different tastes for the alternatives, and for value pricing in particular. Another potentially useful technique is market segmentation. Rather than assume the same model structure and the same values of the coefficients for all decision makers, market segmentation assumes that decision makers belonging to different segments have a completely different set of

preferences (60). Typically, the population is divided into segments based on gender, or age, or some other demographic attribute. In this study, four segments are defined based on choice set. This market segmentation allows for the condition that individuals with the same socioeconomic characteristics who choose from different choice sets may have completely different preferences for value pricing. For example, decision makers who choose from the minimum choice set may be more willing to trade money for travel time savings, and therefore exhibit a higher average value of time, than decision makers who choose from more diverse choice sets.

To test for systematic variations in the preferences, the same model specification is estimated on the pooled data and also on each subset of the data. Ben-Akiva and Lerman (22) refer to this as the test of taste variations. The test assumes the same specification for all market segments ($r = 1, \dots, 4$). The estimation procedure is applied to full data set, the Endure segment ($r = 1$), the Carpooler segment ($r = 2$), the Shifter segment ($r = 3$), and the Avoider segment ($r = 4$). The null hypothesis of no taste variations across the market segments is:

$$H_0 : \beta^1 = \beta^2 = \beta^3 = \beta^4 \quad (14.1)$$

where

β^1 = the vector of coefficients of the Endurer segment

β^2 = the vector of coefficients of the Carpooler segment

β^3 = the vector of coefficients of the Shifter segment, and

β^4 = the vector of coefficients of the Avoider segment.

N is the full sample size ($N = 797$). Denote by N_r the sample size of market segment $r = 1, \dots, R$,²⁶ where R is the number of market segments and

$$\sum_{r=1}^R N_r = N. \quad (14.2)$$

The LR test statistic is given by:

$$-2 \left[L_N(\hat{\beta}) - \sum_{r=1}^R L_{N_r}(\hat{\beta}^r) \right] \quad (14.3)$$

where

$L_N(\hat{\beta})$ = the log likelihood of the model estimated with the full data set, and

$L_{N_r}(\hat{\beta}^r)$ = the log likelihood of the model estimated with the r th subset.

This test statistic is χ^2 distributed with degrees of freedom equal to the number of restrictions,

$$\left[\sum_{r=1}^R (S+T)_r \right] - (S+T) \quad (14.4)$$

where

$(S+T)_r$ = the number of coefficients in the r th market segment model, and

$S+T$ = the number of coefficients in the model estimated with the full data.

²⁶ Sample sizes given previously in Table 14.2 and also in Table 14.4.

The model specification originally presented as Model G.4.C is assumed for each market segment and the estimation procedure is applied separately to Endurers, Carpoolers, Shifters, and Avoiders. The resulting vectors of coefficients are presented in Table 14.4. The corresponding z statistic is given in parentheses and coefficients that are not statistically significant at the 10% level are flagged with an asterisk. By inspection of these, it can be seen that a number of the coefficients found to be statistically different from zero at the 10% level in the pooled estimation are not significant across all four segments. In addition, the choice set based models vary in the mean value of time as evaluated by the β_2/β_1 ratio and shown in the lower portion of the table. For value of time, the range is from \$1.72 per hour for Carpoolers to \$15.22 for Avoiders. These and other potential differences are examined more closely immediately following the test of taste variations.

As shown in the final row of Table 14.4, the number of estimated coefficients ($S + T$), varies from segment to segment. When, for example, Endurers are constrained to their considered choice set, a zero probability for choosing alternatives involving ridesharing or shoulder period travel is assumed and it is not meaningful to estimate δ_1 , δ_2 , δ_3 , or β_8 . This is why there are just five Endurer model coefficients ($\hat{\beta}^1 = [\beta_1, \beta_2, \beta_5, \beta_6, \beta_9]'$).

Table 14.4 Estimated Coefficients for Pooled Sample and Choice Set Segments

Variable	Coef.	Model G.4.C Pooled	$r = 1$ Endurers	$r = 2$ Carpoolers	$r = 3$ Shifters	$r = 4$ Avoiders
$RShare_j * Peak_j$	δ_1	- 1.191 (-4.53)		+ 0.212 (0.27) *		- 1.360 (-3.27)
$Solo_j * Shldr_j$	δ_2	- 2.221 (-9.65)			- 2.188 (-6.93)	- 2.121 (-516)
$RShare_j * Shldr_j$	δ_3	- 2.218 (-6.79)				- 2.260 (-4.49)
$PCost_{jn}$	β_1	- 0.517 (-6.58)	- 1.430 (-3.93)	- 1.152 (-2.89)	- 0.470 (-3.96)	-0.339 (-2.25)
$TTime_{jn}$	β_2	- 0.082 (-6.42)	- 0.284 (-3.62)	- 0.033 (-0.76) *	- 0.077 (-4.29)	-0.086 (-3.82)
$Toll_j * Male_n$	β_5	- 0.668 (-4.14)	- 0.675 (-1.28) *	+ 0.146 (0.24) *	- 0.916 (-3.72)	- 0.584 (-2.17)
$Toll_j * MidAge_n$	β_6	+ 0.177 (1.16) *	+ 1.305 (2.41)	+ 0.091 (0.16) *	+ 0.246 (1.07) *	- 0.206 (-0.76) *
$RShare_j * FMale_n * HHChild_n$	β_8	+ 0.943 (2.95)		+ 0.700 (0.81) *		+ 1.099 (3.18)
$Toll_j * Income_n$	β_9	+ 0.076 (3.58)	+ 0.105 (1.23) *	+ 0.160 (1.71)	+ 0.091 (2.62)	+ 0.061 (1.81)
VOT (\$ per hr); $\beta_2 / \beta_1 * 60 =$		\$ 9.52	\$ 11.92	\$ 1.72	\$ 9.83	\$ 15.22
Log-likelihood; $L_{N_r}(\hat{\beta}^r)$		- 1037.8	- 57.0	- 63.7	- 464.1	- 436.5
N_r		797	117	72	363	245
$(S + T)_r$		9	5	7	6	9

* Coefficient not significant at the 10% level

The LR test statistic given by Equation 14.3 is $-2[-1037.8 - (-1021.3)] = 33.0$ with $27 - 9 = 18$ degrees of freedom. Based on these figures, the null hypothesis of equal coefficients across market segments is rejected at the 10% level ($33.0 > \chi^2_{c(0.90,18)} = 26.0$). Thus, it appears that compared to the pooled model, four segment-specific models are preferable. For the unweighted estimation, the LR test statistic is $-2[-1020.4 - (-1003.0)] = 34.8$, and the conclusion is the same. Based on the LR test results, it appears that the following statement is true. Assuming the same values of the unknown parameters for all decision makers has the problem of failing to capture differences in the values of taste parameters among the choice set groups.

Comparing Choice Behavior Across Market Segments

Rejecting the hypothesis of equal coefficients across the choice set market segments suggests further exploration to discover if statistically significant differences can be attributed to specific variables. For example, by inspection of the coefficient for the age variable $Toll_j * MidAge_n$ (β_6), it can be seen that β_6 is significantly different from zero at the 10% level in the Endurer-specific model, but not in the other three models. Likewise, the coefficient for the income variable $Toll_j * Income_n$ (β_9) is *not* significant at the 10% level in the Endurer-specific model, but *is* significant in the others. The following illustration demonstrates the effects of these apparently unstable estimates on the segment-specific choice probabilities.

The estimates for β_6 and β_9 can be interpreted to mean that for Endurers, the effect on the probability of choosing a tollway alternative of being in the 30 – 49 age group (which reduces the disutility by +1.305) is as great as the effect of an additional \$125,000 in household income (which reduces the disutility by $+0.105 * 12.5 = +1.260$).

By comparison, the effect for Shifters of being in the 30 – 49 age group is no greater than the effect of an additional \$30,000 in household income. And for Avoiders, being in the 30 – 49 age group appears to have the opposite effect on disutility, and actually *reduces* the probability of using a tollway. Another interpretation is that wherever β_6 is flagged with an asterisk, the coefficient is basically zero and therefore the variable $Toll_j * MidAge_n$ is relatively unimportant in predicting the choice probabilities among Carpoolers, Shifters, and Avoiders, but is important in predicting the choice probabilities among Endurers.

Another basis for comparing choice behavior across the four groups is the value of time implied by each. By inspection of the ‘VOT’ row near the bottom of Table 14.4, it can be seen that the implied VOT for Carpoolers (\$1.72 per hour) is substantially lower than for the other groups. Later in this section, a different model structure is assumed and estimated for the Carpooler segment and the VOT for Carpoolers is shown to be in the \$4 – \$5 per hour range. Either way, the lower VOT for the Carpooler group supports the familiar notion that ridesharing and participating in passenger pickup and drop off activities at the trip ends necessarily implies a low value for travel time. As the group with the lowest VOT, Carpoolers are the least likely to choose the Pay alternative and pay the full price toll, as demonstrated earlier in Section 12 (see Table 12.1).

Like Carpoolers, Avoiders also have a non zero probability for using the rideshare mode. It is therefore curious that for Avoiders, the same model estimation implies a substantially greater mean value of time (\$15.22 per hour). Within the Avoider group there is no evidence that a demonstrated willingness to rideshare is associated with a low value for travel time. Rather, it seems plausible that Avoiders may be persons who have a relatively strong aversion to traveling in congested conditions, and because of the high value placed on travel time, they are motivated to consider a diverse set of options for avoiding or bypassing peak period congestion, and are more willing to pay for tollway travel.

Compared to Avoiders, Endurers are positioned at the opposite end of the spectrum in terms of choice set size, yet they exhibit the second highest value of time among the four groups (\$11.92 per hour). More so than others, Endurers are constrained by lifestyle and/or psychological factors to the point that they perceive neither ridesharing nor shoulder period travel as feasible alternatives. This can be interpreted to mean that Endurers have an anti-ridesharing / anti-shoulder bias that is strong relative to their value of travel time; so strong that the biases affect choice set formation. Consequently, they perceive neither ridesharing nor shoulder period travel as feasible alternatives and are more likely than others to choose the Endure alternative.

By inspection of the Endurer and Shifter models in Table 14.4, it appears that the mean value of time for Endurers (\$11.92) is greater than the mean value of time for Shifters (\$9.83). One possible explanation is that Shifters have the option, for example, of trading an early departure for travel time savings, and are therefore less willing than Endurers to trade money for travel time savings. This explanation does not appear to hold true for Avoiders. Compared to Endurers, Avoiders have *several* 'toll free' options for avoiding or bypassing congestion, yet appear *more* willing than Endurers to trade money for travel time savings.

A Separate Model Structure for Carpoolers

The market segmentation shown previously in Table 14.4 allows segment-specific values of the unknown parameters, but assumes the same model structure for each group. Here, the opportunity to specify an entirely different model structure is explored specifically for Carpoolers. The Carpooler segment is selected for this exercise because there is evidence to suggest that the current model structure may not be a particularly good choice for Carpoolers. As shown in Table 14.4, the estimate of δ_1 for Carpoolers is unexpectedly positive (+ 0.212) and not statistically different from zero at the 10%

level ($z = 0.27$).²⁷ One interpretation is that compared to Avoiders, Carpoolers have a lesser anti-ridesharing bias, and that the anti-ridesharing bias for Carpoolers is effectively zero. Regarding the latter, the implication is that when travel times are equal Carpoolers are basically indifferent between the Endure and Carpool alternatives. While this may not be untrue, the possibility remains that this unexpected finding is the result of an improperly specified model.

A separate model structure is evaluated specifically for Carpoolers in which δ_1 is dropped and the variables $\beta_3 * Solo_j * TTime_n$ and $\beta_4 * RShare_j * TTime_n$ replace $\beta_2 * TTime_n$. This allows for the condition that the disutility of one minute spent in rideshare travel is different than the disutility of one minute spent in solo travel. Three different versions of this model structure are estimated on the Carpooler segment of the sample. The estimates for the coefficients and the associated z test statistics are given in Table 14.5. As shown, Model CP.1 is the minimum model, which includes only the cost and time variables. Model CP.2 is the full model, which incorporates the same set of socioeconomic variables represented in the preferred generic model. Model CP.3 is a third specification equivalent to Model CP.2 minus the variables in Model CP.2 that are not statistically significant at the 10% level. Model CP.1 through Model CP.3 are referred to collectively herein as the new Carpooler models.

²⁷ The null hypothesis that between Carpoolers and Avoiders δ_1 is equal is rejected at the 10% level (see Ben-Akiva and Lerman (22, p. 202) for the asymptotic t test of equality of individual coefficients between market segments).

Table 14.5 New Carpooler Models CP.1 – CP.3

Variable	Coef.	Model CP.1 Minimum	Model CP.2 Full	Model CP.3
$RShare_j * Peak_j$	δ_1			
$PCost_n$	β_1	- 0.728 (-3.58)	- 1.322 (-3.37)	- 1.299 (-3.41)
$TTime_n$	β_2			
$Solo_j * TTime_n$	β_3	- 0.108 (-2.61)	- 0.088 (-1.95)	- 0.092 (-2.07)
$RShare_j * TTime_n$	β_4	- 0.127 (-2.27)	- 0.107 (-1.76)	- 0.109 (-1.83)
$Toll_j * Male_n$	β_5		+ 0.115 (0.19) *	
$Toll_j * MidAge_n$	β_6		+ 0.077 (0.14) *	
$RShare_j * FMale_n * HHChild_n$	β_8		+ 0.862 (1.01) *	
$Toll_j * Income_n$	β_9		+ 0.159 (1.70)	+ 0.165 (2.02)

Table 14.5 continued

Variable	Coef.	Model CP.1 Minimum	Model CP.2 Full	Model CP.3
Mean SOV VOT (\$ per hr); $\beta_3 / \beta_1 * 60 =$		\$ 8.90	\$ 3.99	\$ 4.25
Mean HOV VOT (\$ per hr); $\beta_4 / \beta_1 * 60 =$		\$ 10.63	\$ 4.86	\$ 5.03
Log-likelihood (L)		- 65.9	- 63.1	- 63.7

As shown by each of the model estimations given in Table 14.5, the relative magnitudes of the two time coefficients ($\beta_3 > \beta_4$) indicate that one minute of rideshare travel is associated with greater disutility than a one minute of solo travel. Given that the study period is dominated by home-to-work and work-to-home trips and these are not the trips for which travelers usually find it more convenient or desirable to travel with other people, any one of the new Carpooler models in Table 14.5 is more intuitively pleasing than the original Carpooler model presented in Table 14.4. Based on the LR tests in Table 14.6, Model CP.3 is particularly favorable.

Table 14.6 LR Tests to Compare Model CP.1, Model CP.2, and Model CP.3

Test No.	H_0	χ^2	P-value	Reject H_0 at $\alpha = 0.10$
CP2.CP3	$\beta_5 = \beta_6 = \beta_8 = 0$	1.20	0.753	No
CP2.CP1	$\beta_9 = 0$	4.4	0.037	Yes

Compared to the original Carpooler model in Table 14.4, Model CP.3 appears to be a better choice for characterizing the behavior of persons who choose from the Carpooler choice set. This is an example of assuming different model structures for different choice set groups. The original Carpooler estimation assumes the same model structure for all decision makers but allows for different values of the taste parameters. When the assumption of the same model structure for the four market segments is also relaxed, the result for Carpoolers is a substantially higher estimate for their value of time. Although not based on formal statistical testing, the comparative evaluation of the original and new Carpooler models is supportive of the following statement. Assuming the same model structure for all decision makers has the problem of failing to capture differences in the values of taste parameters among the choice set groups.

This demonstration concludes the analytical work of this dissertation. The principal findings are summarized in the final section (Section 15), which follows.

15 SUMMARY OF FINDINGS AND RECOMMENDATIONS

Value pricing is often described as tool for managing congestion and enhancing travel choices. Regarding the latter of these two objectives, this author makes an important contribution by examining the set of alternatives among which users evaluate the option of paying a toll, and by showing for the study sample that a user's preference for the pay option depends in part on the particular subset of competing alternatives that he or she evaluates for personal choice.

This dissertation is an empirical study of 797 motorists who in 1995 traveled in the peak direction within the State Route 91 value priced corridor in southern California. Efficient use of the sample was achieved by prescribing no more than four possible choice sets and subdividing the sample into these choice set groups. User specific choice sets were formed empirically based on each person's history of revealed ridesharing and shoulder period travel. This choice set formation procedure virtually guarantees that ridesharing will be excluded from the choice set when the probability of choosing it is zero, and likewise for shoulder period travel. In evaluating choice conditional on choice set, the author was able to compare users who were estimated to consider neither ridesharing nor shoulder period travel versus users who had demonstrated that they consider one or both of these options.

For this dissertation, the science of estimating discrete choice models is both the method and the motivation. The *method* of model estimation is featured in the statistical test for variations in preferences among the identified choice set groups. The *motivation* is to respond to recent studies of value pricing and the revelation of substantial variability in values of time among decision makers (41,42).¹ There is significant interest in modeling the observed heterogeneity in these preferences. This study addresses this problem by revealing a previously overlooked connection between choice set and choice behavior.

¹ Unpublished paper by Small, K., et al. Uncovering the Distribution of Motorists' Preferences for Travel Time and Reliability: Implications for Road Pricing.

Previously, socioeconomic attributes such as gender and income have been used in lieu of knowing the user-specific choice sets, and a single model has been estimated for all decision makers. This author looks beyond the traditional socioeconomic attributes when investigating between-person differences in the responses to value pricing, and tests choice set as an indicator for choice behavior. Among the four choice set groups in the study sample, systematic variations in the values of time are revealed. Specific to the State Route 91 value priced corridor, this author finds that the particular set of alternatives a motorist considers is an indicator for his or her value of time. Based on this finding, this author recommends further study to find out if motorists in other corridors exhibit similar characteristics. Future studies of proposed value pricing projects may benefit from a choice set based approach to market segmentation to identify and explicitly account for differences in the values of time among choice set groups.

The choice model specified in this study is unique among those in the value pricing literature in that mode, route, and time of day choice are modeled jointly in a single model. As described, each element of the universal choice set is a combination of mode, time, and route, wherein there are exactly two alternatives for each choice dimension. Each of the eight combinations are defined and labeled as shown in Table 15.1. In addition, there are four possible choice sets and users are grouped and labeled according to choice set as shown in Table 15.2 .

Table 15.1 Eight Choice Alternatives

Travel Choice	Mode	Time	Route
Endure	Solo	Peak	Free
Carpool	Rideshare	Peak	Free
Pay	Solo	Peak	Tollway
Carpool & Pay	Rideshare	Peak	Tollway
Shift	Solo	Shoulder	Free
Shift & Carpool	Rideshare	Shoulder	Free
Shift & Pay	Solo	Shoulder	Tollway
Sift & Carpool & Pay	Rideshare	Shoulder	Tollway

Table 15.2 Four Choice Set Groups

Endurers	$\{Endure, Pay\}$
Shifters	$\{Endure, Pay, Shift, Shift \& Pay\}$
Carpoolers	$\{Endure, Carpool, Pay, Carpool \& Pay\}$
Avoiders	$\{Endure, Carpool, Pay, Carpool \& Pay, Shift, Shift \& Pay, Shift \& Carpool, Shift \& Carpool \& Pay\}$

This author is pleased to present an empirical model of mode plus route plus time choice, although development of the model was not the primary objective of the study. If it were, one could certainly argue for a more robust model in terms of including additional alternatives and additional choice sets. As specified, the model is adequate for the intended purpose, which is to test for variations in the taste parameters among choice set groups. The preferred specification was estimated under the assumption that everyone chooses from the same universal choice set, re-estimated on the same sample

with each traveler constrained to their assumed choice set, and then re-estimated four times more; once on each choice set group in the sample.

Findings

The log likelihood of the model estimated on the full sample and the sum of the log likelihoods of the four segment-specific models were compared for the test of taste variations. Based on this test, the hypothesis of equal coefficients across market segments was rejected for the study sample. The most important findings associated with this result are listed below. These are specific to the study population and additional research is needed to evaluate the characteristic of users in other corridors.

1. Among the four segment-specific models, the estimated values of time were not equal. The approximate values were < \$5, \$10, \$12, and \$15 per hour for Carpoolers, Shifters, Endurers, and Avoiders, respectively. Under the usual method of estimating a single model for the full sample, these differences were obscured.
2. There was no clear relationship between the size of the choice set and the value of time. The first and second highest estimates are for the segments with the maximum and minimum choice set, respectively. This finding points to the possibility that the constraints that influence choice set formation also systematically influence the choice behavior.
3. Four segment-specific models were preferable to one model estimated on the full sample. When the same model specification was assumed for the four groups, the vectors of the estimate coefficients were not equal, and there were differences among them in terms of the subset of coefficients that were statistically significant at the 10% level. The coefficient for income was

significant at the 10% level for all but the Endurer group. The travel time coefficient was significant at the 10% level for all but the Carpooler group.

Prior to the model estimation portion of this dissertation, the descriptive analyses for estimating the choice sets and examining choice given choice set revealed substantial new information about travelers and travel behavior in the State Route 91 value priced corridor. Key findings related to these preliminary analyses are listed here. These are specific to the study population.

1. No more than 11.9 percent of women and 16.1 percent of men had a choice set equal to the specified minimum choice set. Thus, a majority of the State Route 91 commuters exhibited some flexibility in their trip making.
2. The null hypothesis that gender and choice set are independent was rejected at the 10 percent level. Women were as likely as men to consider shoulder period travel, and were more likely than men to consider ridesharing.
3. Women were more likely than men to consider the universal choice set. At least 39.4 percent of women and 24.1 percent of men had choice set equal to the specified maximum choice set.
4. Only among women were the attributes of household structure, household income, and education associated with choice set.
5. Route choice for the most recent trip was conditional on choice set, with 30.0 percent of Endurers versus 41.2 percent of Avoiders using a tollway for their most recent peak direction trip. Compared to Endurers, Carpoolers had a larger choice set, yet are no more likely to use tollways.
6. Although gender appears to be associated with route choice within the overall population, there was no indication that this is true for the Carpooler segment of the population. Among Carpoolers, men are as likely as women to use tollways.

7. Even though Avoiders consider a more diverse set of alternatives, Avoiders were as likely as Shifters to travel in a shoulder period. Female Avoiders were more likely than male Avoiders to combine shoulder period travel with tollway travel.

For the study sample, these findings indicate that choice behavior is conditioned on choice set, and that choice set is conditioned on socioeconomic characteristics such as gender and household structure. If these relationships can be validated in other locations, this would make a strong case for modeling choice behavior as a function of socioeconomic user attributes and choice set.

Recommendations

Knowledge of how values of time are distributed among the affected population is important for estimating the impacts of a given value pricing project. Based on the findings of this dissertation, this author makes the following recommendations towards a deeper understanding of how value of time is distributed, and for applying the lessons from this study.

1. Employ a methodology similar to the one used by this author to investigate choice behavior conditional on choice set in other value pricing settings (e.g., Houston, San Diego) to find out how values of time are distributed among different choice set groups in these locations. Refine the methodology by estimating the choice sets independent of the revealed choice for model calibration.
2. When evaluating a proposed value pricing project, look beyond the usual socioeconomic attributes of gender and income when defining different user groups and estimating the choices people will make. As shown in Section 8, statistical testing among the transponder owners in the sample found that

most of the usual socioeconomic characteristics are not associated with the choice of route for the most recent trip.

3. For value pricing projects in locations where the tastes for value pricing are shown to differ among choice set groups, segment the population accordingly and estimate a different discrete choice model for each choice set group. For the eight-alternative model specification featured in this study, this is done under two different assumptions. The first was to assume the same model specification for each group and allow only the model coefficients to vary among the groups (see Table 14.4). The second was to also allow the model specification to vary among the groups (see Table 14.5).
4. Use the same or similar dataset to estimate a discrete choice model for choice set. For the model featured in this study with four choice sets, user attributes such as income, household structure, and education appear to be associated with choice set formation for women, but not for men (see Section 11).
5. Design a study to investigate the lifestyle and attitudinal factors that influence choice set formation.
6. Design a long term study to observe the effect on choice set formation of introducing new travel choices (e.g., add a carpool lane, convert to a high occupancy toll lane).

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APPENDIX A

QUESTIONNAIRE WITH LOGIC & SKIP PATTERNS

QUESTIONNAIRE = SR91RAN

```
*****
*          CODE BOX :          *
*          *                   *
* LT = LESS THAN      ( < ) *
* GT = GREATER THAN   ( > ) *
* EQ = EQUALS         ( = ) *
* NE = NOT EQUAL TO   ( # ) *
*****
```

HELLO THIS IS _____. CALTRANS IS INVESTIGATING TRAVEL PATTERNS IN AND AROUND THE 91 CORRIDOR. WE ARE CONDUCTING A SURVEY OF PEOPLE WHO TRAVEL ON SR91 BETWEEN ORANGE AND RIVERSIDE COUNTIES. I'D LIKE TO ASK YOU A FEW QUESTIONS. IT WILL ONLY TAKE A FEW MINUTES (5-6). CAN YOU HELP ME OUT ? GREAT.

```
*****
1. NOW, OR AT ANY TIME DURING THE PAST TWO YEARS, HAVE YOU OR ANYONE
   IN YOUR HOUSEHOLD REGULARLY MADE PEAK PERIOD TRIPS ON WEEKDAYS TO
   ORANGE COUNTY OR BEYOND, USING ROUTE 91 OR THE PARALLEL METROLINK ?
   INCLUDE COMMUTING BY BOTH HIGHWAY AND TRANSIT.
```

1. YES, PERSON ON PHONE IS OR WAS A COMMUTER IN THE CORRIDOR
2. YES, OTHER HOUSEHOLD MEMBER IS BUT PERSON ON PHONE ISN'T
3. NO
4. REFUSED

(PROMPT ONLY IF NO ANSWER)

```
SKIP AFTER Q1  IF Q<1> EQ "1" THEN GO 224
SKIP AFTER Q1  IF Q<1> GE "3" THEN GO END
```

```
*****
2. WHEN IS A CONVENIENT TIME TO CALL THIS PERSON AT HOME ?
```

```
SKIP AFTER Q2  GO END
```

```
*****
3. DO YOU NOW REGULARLY MAKE PEAK PERIOD TRIPS ON WEEKDAYS TO ORANGE
   COUNTY OR BEYOND, USING ROUTE 91 OR THE PARALLEL METROLINK ?
   (INCLUDE COMMUTING BY BOTH HIGHWAY AND TRANSIT)
```

1. YES
2. NO
3. REFUSED

(PROMPT ONLY IF NO ANSWER)

```
SKIP AFTER Q3  IF Q<3> EQ "3" THEN GO END
SKIP AFTER Q3  IF Q<3> EQ "1" THEN GO 24
```

```
*****
4. WHY DO YOU NO LONGER MAKE PEAK PERIOD TRIPS IN THE ROUTE 91
   CORRIDOR ?
```

1. EMPLOYMENT PLACE CHANGED OR NO LONGER EMPLOYED

2. HOME LOCATION HAS CHANGED
3. THE NATURE OF MY JOB CHANGED, NO LONGER REQUIRING THAT TRAVEL
4. NOW MOSTLY OR ALWAYS WORK AT HOME
5. I NOW USE A DIFFERENT HIGHWAY TO MAKE THESE TRIPS
6. I NOW TAKE THE BUS, METRORAIL OR RIDESHARE TO WORK
7. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE =

SKIP AFTER Q4 IF Q<4> LE "2" THEN GO END

5. HAVE CHANGES IN TRAVEL CONDITIONS ALONG ROUTE 91 HAD AN EFFECT ON
YOUR DECISION TO AVOID TRAVELING IN THE 91 CORRIDOR DURING PEAK
PERIODS ?

1. YES
2. NO
3. DON'T KNOW/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q5 IF Q<5> GE "2" THEN GO 9

6. WHAT CHANGES IN THE ROUTE 91 CORRIDOR CAUSED YOU TO CHANGE YOUR
PREVIOUS TRAVEL BEHAVIOR ?

1. TRAFFIC IS WORSE
2. TOLLS ARE HIGHER
3. IT'S TOO DANGEROUS OR STRESSFUL TO DRIVE IN PEAK TRAFFIC
4. I'M NO LONGER WILLING TO PAY THE TOLL
5. PARKING AT WORK HAS BECOME MOER DIFFICULT
6. PUBLIC TRANSIT HAS BECOME LESS CONVENIENT
7. I USE THE EASTERN TOLL ROAD (OR TRANSIT) INSTEAD
8. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE =

(Multiple Response)

SKIP AFTER Q6 IF Q<6> EQ "7" THEN GO 24

SKIP AFTER Q6 IF Q<6> EQ "2" THEN GO 7

SKIP AFTER Q6 IF Q<6> EQ "4" THEN GO 7

SKIP AFTER Q6 GO 9

7. WHY ARE YOU NO LONGER WILLING TO PAY TOLLS ?

1. INCOME IS LOWER, CAN'T AFFORD TOLLS
2. OTHER EXPENSES HAVE INCREASED, CAN'T AFFORD TOLLS
3. DO NOT APPROVE OF TOLL ROADS GENERALLY
4. DO NOT APPROVE OF PRIVATE TOLL ROAD COMPANY
5. NO LONGER RIDESHARE AND SPLIT TOLLS
6. NO LONGER RECEIVE EMPLOYER SUBSIDY FOR TOLLS
7. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE =

(Multiple Response)

SKIP AFTER Q7 IF Q<7> LE "2" THEN GO 9
 SKIP AFTER Q7 IF Q<7> GE "5" THEN GO 9

8. CAN YOU TELL ME WHY YOU DON'T APPROVE OF THE TOLLS/COMPANY ?

9. I'D LIKE TO ASK YOU SOME GENERAL QUESTIONS ABOUT YOUR OPINIONS ON THE
 91 EXPRESS LANES. THE AMOUNT CHARGED ON THE EXPRESS LANES VARIES BASED
 ON THE AMOUNT OF CONGESTION THE USER AVOIDS. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

10. ADDITIONAL EXPRESS TOLL LANES FOR BYPASSING CONGESTION COULD BE
 CONSTRUCTED ALONG OTHER CONGESTED HIGHWAYS IN CALIFORNIA. DO YOU
 THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

11. PRIVATE COMPANIES SHOULD BE ALLOWED TO OPERATE TOLL ROADS AS A
 PROFIT MAKING BUSINESS. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

12. SINGLE OCCUPANT VEHICLES COULD BE ALLOWED TO PAY TOLLS TO USE
 UNDER-USED CARPOOL LANES TO AVOID CONGESTION AS LONG AS THESE
 LANES DON'T BECOME CONGESTED. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q12 IF Q<12> NE "2" THEN GO 15

13. WHY DO YOU THINK THIS IS A BAD IDEA ?

1. ONLY BENEFITS THE RICH
2. NOT FAIR TO HAVE TOLLS ON ROADS WE'VE ALREADY PAID FOR
3. GOVERNMENT WILL WASTE THE MONEY
4. WILL INCREASE GOVERNMENT BUREAUCRACY
5. WILL DISCOURAGE CARPOOLING
6. BAD FOR THE ENVIRONMENT
7. WILL DISCOURAGE IMPROVEMENT/EXPANSION OR REGULAR HIGHWAYS
8. ROADS SHOULD BE FREE TO ALL
9. TOO COMPLICATED AND CONFUSING
10. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCHES TO
ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE =

(Multiple Response)

15. WHAT IS YOUR HOME ZIP CODE ?

16. IF YOU ARE NOW EMPLOYED, WHAT KIND OF WORK DO YOU DO ?

1. SECRETARIAL/CLERICAL
2. PRODUCTION/CRAFTS/OFFICE WORK
3. SENIOR MANAGEMENT
4. MIDDLE MANAGEMENT
5. MAINTENANCE
6. SALES/SERVICE
7. PROFESSIONAL
8. CONSTRUCTION
9. MILITARY
10. OTHER
11. REFUSED
12. RETIRED
13. STUDENT
14. UNEMPLOYED (OTHER LINE = 320)

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q16 IF Q<16> GE "11" THEN GO 18

17. DO YOU WORK FULL TIME OR PART TIME ?

1. FULL TIME
2. PART TIME
3. OTHER
4. DON'T KNOW/REFUSED (OTHER LINE = 321)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q17 IF Q<17> LE "3" THEN GO 217

18. PLEASE STOP ME WHEN I SAY THE CATEGORY THAT INCLUDES YOUR AGE.

1. IN YOUR 20'S
2. 30'S
3. 40'S
4. 50'S
5. OVER 60
6. REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

19. PLEASE STOP ME WHEN I SAY THE HIGHEST GRADE OF SCHOOL THAT YOU HAVE COMPLETED SO FAR ?

1. HIGH SCHOOL OR LESS
2. SOME COLLEGE, TRADE OR VOCATIONAL SCHOOL
3. GRADUATED COLLEGE WITH BACHELOR'S DEGREE
4. GRADUATE WORK BEYOND BACHELOR'S DEGREE
5. DON'T KNOW/REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

 20. PLEASE STOP ME WHEN I SAY THE CATEGORY THAT INCLUDES YOUR
 HOUSEHOLD'S TOTAL INCOME FOR 1998 BEFORE TAXES.

1. LESS THAN \$10,000
2. \$10,000 - \$25,000
3. \$25,000 - \$40,000
4. \$40,000 - \$60,000
5. \$60,000 - \$100,000
6. \$100,000 AND ABOVE
7. REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

 21. GENDER ?

*** SURVEYOR NOTE: COMPLETE BY OBSERVATION ***

1. MALE
2. FEMALE

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q21 GO 212

 22. MAY WE CONTACT YOU FOR A FOLLOW-UP SURVEY ?

1. YES
2. NO
3. OTHER (OTHER LINE = 322)

(DON'T READ PRE-CODED RESPONSES)

 23. MAY I HAVE YOUR FIRST AND LAST NAME PLEASE ?

SKIP BEFORE Q23 IF Q<22> EQ "2" THEN GO END
 SKIP AFTER Q23 GO END

 24. ENTER THE TRIP TO ASK ABOUT.

1. WESTBOUND
2. EASTBOUND

Rotates pre-coded responses

(DON'T READ PRE-CODED RESPONSES)

 25. DURING THE PAST MONTH, DID YOU MAKE ANY MORNING TRIPS INTO
 ORANGE COUNTY BETWEEN 4AM AND 10AM, ON MONDAY THROUGH
 THURSDAY ?

1. YES MADE TRIP
2. YES, BUT MORE THAN A MONTH AGO
3. NO, DON'T MAKE SUCH TRIPS/REFUSED
4. I TRAVEL INTO ORANGE COUNTY, BUT AT A DIFFERENT TIME
5. DON'T REMEMBER
6. REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q25 IF Q<24> NE "1" THEN GO 26
 SKIP AFTER Q25 IF Q<25> GE "2" THEN GO 58

 26. DURING THE PAST MONTH, DID YOU MAKE ANY AFTERNOON OR EVENING
 TRIPS OUT OF ORANGE COUNTY BETWEEN 2PM AND 8PM ON MONDAY
 THROUGH THURSDAY ?

 1. YES MADE TRIP
 2. YES, BUT MORE THAN A MONTH AGO
 3. NO, DON'T MAKE SUCH TRIPS/REFUSED
 4. I TRAVEL OUT OF ORANGE COUNTY, BUT AT A DIFFERENT TIME
 5. DON'T REMEMBER
 6. REFUSED

 (DON'T READ PRE-CODED RESPONSES)

 SKIP BEFORE Q26 IF Q<24> NE "2" THEN GO 27
 SKIP AFTER Q26 IF Q<26> GE "2" THEN GO 58

 27. ON WHICH DAY OF THE WEEK DID YOU MAKE YOUR MOST RECENT
 TRIP OF THIS TYPE ?

 1. MONDAY
 2. TUESDAY
 3. WEDNESDAY
 4. THURSDAY

 (PROMPT ONLY IF NO ANSWER)

 29. WHAT WAS THE PRIMARY PURPOSE OF THE TRIP ?

 1. HOME TO WORK
 2. HOME TO PERSONAL BUSINESS/SHOPPING
 3. HOME TO RECREATION OR LEISURE
 4. WORK RELATED TRIP (OR EMPLOYER'S BUSINESS)
 5. HOME TO SCHOOL
 6. WORK TO HOME
 7. PERSONAL BUSINESS OR SHOPPING TO HOME
 8. SCHOOL TO HOME
 9. RECREATION OR LEISURE ACTIVITY TO HOME
 10. PERSONAL TRIPS NEITHER END AT HOME
 11. OTHER (COMMENT) (OTHER LINE = 323)

 (PROMPT ONLY IF NO ANSWER)

 30. HOW DID YOU MAKE THIS TRIP ? DID YOU . . . ?

 1. DRIVE ALONE
 2. 2 PERSON CARPOOL (AS DRIVER OR PASSENGER)
 3. 3+ PERSON CARPOOL (AS DRIVER OR PASSENGER)
 4. COMPANY VANPOOL (AS DRIVER OR PASSENGER)
 5. BUS
 6. METROLINK
 7. MOTORCYCLE
 8. OTHER COMMENT (OTHER LINE = 324)

 (READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

 SKIP AFTER Q30 IF Q<30> EQ "5" THEN GO 41
 SKIP AFTER Q30 IF Q<30> EQ "6" THEN GO 41

31. INCLUDING YOURSELF, HOW MANY PEOPLE WERE IN THE VEHICLE ?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7 OR MORE

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q31 IF Q<30> LE "2" THEN GO 32
SKIP BEFORE Q31 IF Q<30> EQ "7" THEN GO 32

32. ON THIS TRIP DID YOU:

1. USE THE ROUTE 91 TOLL LANES
2. USE THE NEW EASTERN TOLL ROAD
3. USE THE ROUTE 91 FREE LANES (AND NEITHER TOLL FACILITY)
4. USE ANOTHER ROUTE (GET ROUTE IN COMMENT) (OTHER LINE = 325)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

33. DID YOU MAKE ANY STOPS DURING THE TRIP SUCH AS STOPS FOR GAS, FOOD
OR PICKING UP/DROPPING OFF SOMEONE (OTHER THAN A CARPOOL MEMBER)

*** SURVEYOR NOTE: INCLUDE PHRASE ONLY IF IN CARPOOL/VANPOOL***

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q33 IF Q<33> GE "2"
AND Q<30> EQ "1" THEN GO 41
SKIP AFTER Q33 IF Q<33> GE "2"
AND Q<30> GE "5" THEN GO 41
SKIP AFTER Q33 IF Q<33> GE "2" THEN GO 35

34. WHAT WERE THOSE STOPS FOR ?

1. SHOPPING
2. WORK-RELATED ERRAND
3. NON-WORK ERRAND
4. PICK UP OR DROP OFF ADULT PASSENGER(S)
5. PICK UP OR DROP OFF CHILD OR CHILDREN
6. MEAL OR SNACK
7. OTHER (COMMENT) (OTHER LINE = 326)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q34 IF Q<30> EQ "1" THEN GO 41
SKIP AFTER Q34 IF Q<30> GE "5" THEN GO 41

35. ABOUT WHAT TIME IN THE MORNING WERE ALL PASSENGERS TOGETHER IN

THE VEHICLE AND THE TRIP BEGAN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q35 IF Q<24> NE "1" THEN GO 187

36. IN WHAT CITY WAS EVERYONE TOGETHER IN THE VEHICLE AND THAT
TRIP BEGAN ?

37. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

SKIP AFTER Q37 GO 222

38. DID THE RIDESHARE GROUP SPLIT SOME OR ALL OF THE TRAVEL COSTS ?

1. YES
2. NO
3. NO RESPONSES, REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q38 IF Q<38> GE "2" THEN GO 44

39. ABOUT HOW MUCH WAS YOUR SHARE OF THE COST ?

40. IS THIS . . . ?

1. PER TRIP
2. PER DAY
3. PER WEEK
4. PER MONTH
5. OTHER (OTHER LINE = 327)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q40 GO 44

41. ABOUT WHAT TIME IN THE MORNING DID THIS TRIP BEGIN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM
AND PM IS VERY IMPORTANT ***

SKIP BEFORE Q41 IF Q<24> NE "1" THEN GO 188

42. IN WHAT CITY DID THE TRIP BEGIN ?

43. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

SKIP AFTER Q43 IF Q<30> EQ "5" THEN GO 49

SKIP AFTER Q43 IF Q<30> EQ "6" THEN GO 49

44. ABOUT WHAT TIME IN THE MORNING DID YOU PASS THE ENTRANCE OF THE
SR91 EXPRESS LANES GOING WESTBOUND INTO ORANGE COUNTY ? (AT THE
RIVERSIDE COUNTY - ORANGE COUNTY LINE)

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q44 IF Q<24> NE "1" THEN GO 45
SKIP AFTER Q44 IF Q<30> EQ "1" THEN GO 49
SKIP AFTER Q44 IF Q<30> GE "7" THEN GO 49

45. ABOUT WHAT TIME IN THE EVENING DID YOU PASS THE ENTRANCE OF THE
SR91 EXPRESS LANES GOING EASTBOUND OUT OF ORANGE COUNTY ?
(AT THE JUNCTION OF SR91 AND SR55)

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q45 IF Q<24> NE "2" THEN GO 46
SKIP AFTER Q45 IF Q<30> EQ "1" THEN GO 49
SKIP AFTER Q45 IF Q<30> GE "7" THEN GO 49

46. ABOUT WHAT TIME IN THE MORNING DID THE FIRST PASSENGER GET TO
THEIR DESTINATION ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q46 IF Q<24> NE "1" THEN GO 189

47. IN WHAT CITY DID THE FIRST PASSENGER END THEIR TRIP ?

48. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

SKIP AFTER Q48 GO 52

49. APPROXIMATELY WHAT TIME IN THE MORNING DID YOUR TRIP END ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q49 IF Q<24> NE "1" THEN GO 190

50. IN WHAT CITY DID YOUR TRIP END ?

51. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

52. FOR THIS TRIP, WAS YOUR ARRIVAL TIME SET OR WAS IT UP TO YOU ?

1. ARRIVAL TIME SET
2. ARRIVAL TIME UP TO ME
3. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q52 IF Q<24> NE "1" THEN GO 54
SKIP AFTER Q52 IF Q<52> EQ "1" THEN GO 58
SKIP AFTER Q52 IF Q<52> EQ "3" THEN GO 58

53. HOW DID YOU DECIDE ON YOUR ARRIVAL TIME ?

1. TO ARRIVE AT THE SAME TIME EVERYONE ELSE ARRIVES
2. TO AVOID PEAK AM CONGESTION
3. TO COORDINATE WITH MY RIDESHARE GROUP
4. TO MEET BUS/TRAIN SCHEDULE
5. ARRIVED WHEN I COULD OR WAS READY
6. ARRIVED EARLY IN CASE OF AN UNEXPECTED DELAY
7. ARRIVED EARLY IN ORDER TO LEAVE EARLY
8. ARRIVED LATE IN ORDER TO STAY LATE
9. OTHER
10. DON'T KNOW/REFUSED (OTHER LINE = 354)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q53 GO 58

54. FOR THIS TRIP, WAS YOUR DEPARTURE TIME SET OR WAS IT UP TO YOU ?

1. DEPARTURE TIME SET
2. DEPARTURE TIME UP TO ME
3. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q54 IF Q<54> EQ "1" THEN GO 58

SKIP AFTER Q54 IF Q<54> EQ "3" THEN GO 58

55. HOW DID YOU DECIDE ON YOUR DEPARTURE TIME ?

1. TO LEAVE AT THE SAME TIME EVERYONE ELSE LEAVES
2. TO AVOID PEAK PM CONGESTION
3. TO COORDINATE WITH MY RIDESHARE GROUP
4. TO MEET BUS/TRAIN SCHEDULE
5. I LEFT WHEN I COULD OR WAS READY
6. LEFT EARLY IN CASE OF AN UNEXPECTED DELAY
7. LEFT EARLY BECAUSE I ARRIVED EARLY
8. LEFT LATE BECAUSE I ARRIVED LATE
9. OTHER
10. DON'T KNOW/REFUSED (OTHER LINE = 356)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

58. DURING THE PAST MONTH DID YOU MAKE ANY MORNING TRIPS INTO ORANGE COUNTY BETWEEN 4AM AND 10AM, WHICH OCCURRED ON A FRIDAY ?

1. YES
2. YES, BUT MORE THAN A MONTH AGO
3. NO SUCH TRIPS ON FRIDAY
4. TRAVELED INTO ORANGE COUNTY, BUT AT A DIFFERENT TIME
5. DON'T REMEMBER
6. REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q58 IF Q<24> NE "1" THEN GO 191

SKIP AFTER Q58 IF Q<58> EQ "6" THEN GO 111

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SKIP AFTER Q58 IF Q<58> EQ "5" THEN GO 195
SKIP AFTER Q58 IF Q<58> EQ "4" THEN GO 195
SKIP AFTER Q58 IF Q<58> EQ "3" THEN GO 195
SKIP AFTER Q58 IF Q<58> EQ "2" THEN GO 195
SKIP AFTER Q58 IF Q<58> EQ "1" THEN GO 192
*****
60. I'M NOW GOING TO ASK YOU QUESTIONS ABOUT THE MOST RECENT TRIP
    OF THIS TYPE WHICH OCCURRED ON FRIDAY, WHAT WAS THE PRIMARY
    PURPOSE OF THE TRIP ?

    1. HOME TO WORK
    2. HOME TO PERSONAL BUSINESS/SHOPPING
    3. HOME TO RECREATION OR LEISURE
    4. WORK RELATED TRIP (OR EMPLOYER'S BUSINESS)
    5. HOME TO SCHOOL
    6. WORK TO HOME
    7. PERSONAL BUSINESS OR SHOPPING TO HOME
    8. SCHOOL TO HOME
    9. RECREATION OR LEISURE ACTIVITY TO HOME
    10. PERSONAL TRIP, NEITHER END AT HOME
    11. OTHER (COMMENT) (OTHER LINE = 328)

    (PROMPT ONLY IF NO ANSWER)
    *****
61. HOW DID YOU MAKE THIS TRIP ? DID YOU . . . ?

    1. DRIVE ALONE
    2. 2 PERSON CARPOOL (AS DRIVER OR PASSENGER)
    3. 3+ PERSON CARPOOL (AS DRIVER OR PASSENGER)
    4. COMPANY VANPOOL (AS DRIVER OR PASSENGER)
    5. BUS
    6. METROLINK
    7. MOTORCYCLE
    8. OTHER COMMENT (OTHER LINE = 329)

    (READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

    SKIP AFTER Q61 IF Q<61> EQ "5" THEN GO 72
    SKIP AFTER Q61 IF Q<61> EQ "6" THEN GO 72
    *****
62. INCLUDING YOURSELF, HOW MANY PEOPLE WERE IN THE VEHICLE WITH YOU?

    1. 1
    2. 2
    3. 3
    4. 4
    5. 5
    6. 6
    7. 7 OR MORE

    (DON'T READ PRE-CODED RESPONSES)

    SKIP BEFORE Q62 IF Q<61> LE "2" THEN GO 63
    SKIP BEFORE Q62 IF Q<61> EQ "7" THEN GO 63
    *****
63. ON THIS TRIP DID YOU:

    1. USE THE ROUTE 91 TOLL LANES
    2. USE THE NEW EASTERN TOLL ROAD
    3. USE THE ROUTE 91 FREE LANES - AND NEITHER TOLL FACILITY

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4. USE ANOTHER ROUTE (GET ROUTE IN COMMENT) (OTHER LINE = 330)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

64. DID YOU MAKE ANY STOPS DURING THE TRIP SUCH AS STOPS FOR GAS, FOOD OR PICKING UP/DROPPING OFF SOMEONE (OTHER THAN A CARPOOL MEMBER)

*** SURVEYOR NOTE: INCLUDE PHRASE ONLY IF IN CARPOOL/VANPOOL***

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q64 IF Q<64> GE "2"
AND Q<61> EQ "1" THEN GO 72

SKIP AFTER Q64 IF Q<64> GE "2"
AND Q<61> GE "5" THEN GO 72

SKIP AFTER Q64 IF Q<64> GE "2" THEN GO 66

65. WHAT WERE THOSE STOPS FOR ?

1. SHOPPING
2. WORK-RELATED ERRAND
3. NON-WORK ERRAND
4. PICK UP OR DROP OFF ADULT PASSENGER(S)
5. PICK UP OR DROP OFF CHILD OR CHILDREN
6. MEAL OR SNACK
7. OTHER (COMMENT) (OTHER LINE = 331)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q65 IF Q<61> EQ "1" THEN GO 72

SKIP AFTER Q65 IF Q<61> GE "5" THEN GO 72

66. ABOUT WHAT TIME IN THE MORNING WERE ALL PASSENGERS TOGETHER IN THE VEHICLE AND THE TRIP BEGAN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q66 IF Q<24> NE "1" THEN GO 198

67. IN WHAT CITY WAS EVERYONE TOGETHER IN THE VEHICLE AND THAT TRIP BEGAN ?

68. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

SKIP AFTER Q68 GO 223

69. DID THE RIDESHARE GROUP SPLIT SOME OR ALL OF THE TRAVEL COSTS ?

1. YES
2. NO
3. NO RESPONSES, REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q69 IF Q<69> GE "2" THEN GO 75

70. ABOUT HOW MUCH WAS YOUR SHARE OF THE COST ?

71. IS THIS . . . ?

1. PER TRIP

2. PER DAY

3. PER WEEK

4. PER MONTH

5. OTHER (OTHER LINE = 332)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q71 GO 75

72. ABOUT WHAT TIME IN THE MORNING DID THIS TRIP BEGIN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM
AND PM IS VERY IMPORTANT ***

SKIP BEFORE Q72 IF Q<24> NE "1" THEN GO 199

73. IN WHAT CITY DID THE TRIP BEGIN ?

74. WHAT WERE THE LOCAL CROSS STREETS THERE ?

*** SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY ***

SKIP AFTER Q74 IF Q<61> EQ "5" THEN GO 80

SKIP AFTER Q74 IF Q<61> EQ "6" THEN GO 80

75. ABOUT WHAT TIME IN THE MORNING DID YOU PASS THE ENTRANCE OF THE SR91
EXPRESS LANES GOING WESTBOUND ? (AT THE RIVERSIDE COUNTY - ORANGE COUNTY
LINE)

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q75 IF Q<24> NE "1" THEN GO 76

SKIP AFTER Q75 IF Q<61> EQ "1" THEN GO 80

SKIP AFTER Q75 IF Q<61> GE "7" THEN GO 80

76. ABOUT WHAT TIME IN THE EVENING DID YOU PASS THE ENTRANCE OF THE SR91
EXPRESS LANES GOING EASTBOUND ? (AT THE JUNCTION OF SR91 AND SR55)

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q76 IF Q<24> NE "2" THEN GO 77

SKIP AFTER Q76 IF Q<61> EQ "1" THEN GO 80

SKIP AFTER Q76 IF Q<61> GE "7" THEN GO 80

77. ABOUT WHAT TIME IN THE MORNING DID THE FIRST PASSENGER GET TO
THEIR DESTINATION ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM

IS VERY IMPORTANT ***

SKIP BEFORE Q77 IF Q<24> NE "1" THEN GO 200

78. IN WHAT CITY DID THE FIRST PASSENGER END THEIR TRIP ?

79. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

SKIP AFTER Q79 GO 83

80. APPROXIMATELY WHAT TIME IN THE MORNING DID YOUR TRIP END ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP BEFORE Q80 IF Q<24> NE "1" THEN GO 201

81. IN WHAT CITY DID YOUR TRIP END ?

82. WHAT WERE THE LOCAL CROSS STREETS THERE ?

SURVEYOR NOTE: ASK FOR SPELLING IF NECESSARY

83. FOR THIS TRIP, WAS YOUR ARRIVAL TIME SET OR WAS IT UP TO YOU ?

1. ARRIVAL TIME SET
2. ARRIVAL TIME UP TO ME
3. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q83 IF Q<24> NE "1" THEN GO 85

SKIP AFTER Q83 IF Q<83> EQ "1" THEN GO 89

SKIP AFTER Q83 IF Q<83> EQ "3" THEN GO 89

84. HOW DID YOU DECIDE ON YOUR ARRIVAL TIME ?

1. TO ARRIVE AT THE SAME TIME EVERYONE ELSE ARRIVES
2. TO AVOID PEAK AM CONGESTION
3. TO COORDINATE WITH MY RIDESHARE GROUP
4. TO MEET BUS/TRAIN SCHEDULE
5. ARRIVED WHEN I COULD OR WAS READY
6. ARRIVED EARLY IN CASE OF AN UNEXPECTED DELAY
7. ARRIVED EARLY IN ORDER TO LEAVE EARLY
8. ARRIVED LATE IN ORDER TO STAY LATE
9. OTHER
10. DON'T KNOW/REFUSED (OTHER LINE = 357)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q84 GO 89

85. FOR THIS TRIP, WAS YOUR DEPARTURE TIME SET OR WAS IT UP TO YOU ?

1. DEPARTURE TIME SET
2. DEPARTURE TIME UP TO ME

3. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q85 IF Q<85> EQ "1" THEN GO 89

SKIP AFTER Q85 IF Q<85> EQ "3" THEN GO 89

86. HOW DID YOU DECIDE ON YOUR DEPARTURE TIME ?

1. TO LEAVE AT THE SAME TIME EVERYONE ELSE LEAVES
2. TO AVOID PEAK PM CONGESTION
3. TO COORDINATE WITH MY RIDESHARE GROUP
4. TO MEET BUS/TRAIN SCHEDULE
5. I LEFT WHEN I COULD OR WAS READY
6. LEFT EARLY IN CASE OF AN UNEXPECTED DELAY
7. LEFT EARLY BECAUSE I ARRIVED EARLY
8. LEFT LATE BECAUSE I ARRIVED LATE
9. OTHER
10. DON'T KNOW/REFUSED (OTHER LINE = 358)

(Multiple Response)

89. WHY WAS THIS TRIP YOU JUST DESCRIBED DIFFERENT FROM YOUR OTHER WEEKDAY TRIP, WHICH YOU TOLD ME ABOUT PREVIOUSLY ? PLEASE IDENTIFY ALL THE REASONS WHY THESE TWO TRIPS WERE MADE DIFFERENTLY.

1. BECAUSE TRAFFIC IS WORSE
2. BECAUSE THE TOLL IS DIFFERENT
3. I HAD DIFFERENT PERSONAL OR WORK ACTIVITY THAT DAY
4. I NEEDED OR DIDN'T NEED MY VEHICLE ON ONE OF THOSE DAYS
5. SOMEONE I TRAVEL WITH HAD A DIFFERENT PERSONAL OR WORK ACTIVITY ONE OF THOSE DAYS
6. SOMEONE I TRAVEL WITH NEEDED OR DIDN'T NEED THEIR VEHICLE ON ONE OF THOSE DAYS
7. MY SCHEDULE WAS DIFFERENT ON THOSE DAYS
8. I OVERSLEPT OR WAS ACCIDENTLY DELAYED ON ONE OF THOSE DAYS
9. OTHER (OTHER LINE = 333)

(Multiple Response)

(PROMPT ONLY IF NO ANSWER)

111. TWO YEARS AGO THIS MONTH, DID YOU REGULARLY MAKE PEAK PERIOD TRIPS ON WEEKDAYS BETWEEN THE SAME LOCATIONS YOU TRAVEL BETWEEN NOW ? (INCLUDE COMMUTING BY BOTH HIGHWAY AND TRANSIT)

1. YES
2. NO
3. DON'T KNOW, DON'T REMEMBER, REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q111 IF Q<111> GE "2" THEN GO 138

112. THINK BACK TO TWO YEARS AGO THIS MONTH AND ABOUT THE NUMBER OF WESTBOUND TRIPS YOU MADE INTO ORANGE COUNTY MONDAY THROUGH FRIDAY BETWEEN 4AM AND 10AM. TWO YEARS AGO WERE YOU USUALLY MAKING:

1. ABOUT THE SAME NUMBER OF TRIPS
2. MORE AM WESTBOUND TRIPS THAN TODAY

3. FEWER AM WESTBOUND TRIPS THAN TODAY
4. DON'T KNOW / DON'T REMEMBER / REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP BEFORE Q112 IF Q<24> NE "1" THEN GO 202
 SKIP AFTER Q112 IF Q<112> EQ "1" THEN GO 115
 SKIP AFTER Q112 IF Q<112> EQ "2" THEN GO 113
 SKIP AFTER Q112 IF Q<112> EQ "3" THEN GO 114
 SKIP AFTER Q112 IF Q<112> EQ "4" THEN GO 115

 113. WHY WERE YOU MAKING MORE PEAK PERIOD TRIPS TWO YEARS AGO ?

1. I WASN'T MAKING MORE TRIPS TWO YEARS AGO
2. TRAFFIC IS WORSE
3. TOLLS ARE HIGHER
4. TRAVELING BY PUBLIC TRANSIT HAS BECOME MORE INCONVENIENT
5. I WORK AT HOME MORE OFTEN
6. SOME OR ALL TRIPS HAVE SHIFTED TO OFF-PEAK TIMES
7. PARKING AT WORK HAS BECOME MORE DIFFICULT
8. I NOW WORK FEWER DAYS PER WEEK
9. MY WORK REQUIRES ME TO TRAVEL ELSEWHERE
10. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
 ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

SKIP AFTER Q113 GO 115

 114. WHY WERE YOU MAKING FEWER PEAK PERIOD TRIPS TWO YEARS AGO ?

1. I WASN'T MAKING FEWER TRIPS TWO YEARS AGO
2. I NOW USE THE ROUTE 91 EXPRESS LANES AND FIND TRAVEL EASIER
3. I NOW USE THE EASTERN TOLL ROAD AND FIND TRAVEL EASIER
4. I SWITCHED TO RIDESHARE AND FIND TRAVEL EASIER
5. I SWITCHED TO DRIVE ALONE AND FIND TRAVEL EASIER
6. I SWITCHED TO METROLINK AND FIND TRAVEL EASIER
7. I NOW WORK MORE DAYS PER WEEK
8. PARKING AT WORK HAS BECOME EASIER
9. MY WORK REQUIRES ME TO TRAVEL HERE MORE OFTEN
10. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
 ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

115. COMPARING YOUR PRESENT TYPICAL MORNING WESTBOUND PEAK PERIOD TRAVEL
 MONDAY THROUGH FRIDAY TO TWO YEARS AGO, HAS THE OVERALL AMOUNT YOU
 DRIVE ALONE, CARPOOL OR TAKE TRANSIT CHANGED ?

1. YES
2. NO
3. DON'T REMEMBER
4. REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q115 IF Q<24> NE "1" THEN GO 203
 SKIP AFTER Q115 IF Q<115> EQ "1" THEN GO 204
 SKIP AFTER Q115 IF Q<115> EQ "3" THEN GO 116
 SKIP AFTER Q115 IF Q<115> EQ "4" THEN GO 138

116. IN THE MORNING PEAK PERIOD TRAVELING WESTBOUND INTO ORANGE COUNTY, MONDAY THROUGH FRIDAY, IS THE AMOUNT YOU NOW USE THE ROUTE 91 TOLL LANES GREATER OR LESS THAN TWO YEARS AGO ?

1. GREATER
2. LESS
3. NO CHANGE
4. DON'T REMEMBER
5. I NEVER USE THE 91 TOLL LANES
6. REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q116 IF Q<24> NE "1" THEN GO 206
 SKIP AFTER Q116 IF Q<116> EQ "1" THEN GO 135
 SKIP AFTER Q116 IF Q<116> EQ "3" THEN GO 136
 SKIP AFTER Q116 IF Q<116> EQ "4" THEN GO 136
 SKIP AFTER Q116 IF Q<116> EQ "5" THEN GO 136
 SKIP AFTER Q116 IF Q<116> EQ "6" THEN GO 138

134. WHY HAS THE AMOUNT YOU USE THE ROUTE 91 TOLL LANES DECREASED SINCE TWO YEARS AGO ?

1. TRAFFIC IS LESS CONGESTED
2. TOLLS ARE HIGHER
3. I USE THE EASTERN TOLL ROAD INSTEAD
4. MY INCOME HAS CHANGED
5. I'M NO LONGER WILLING TO PAY THE TOLL
6. GREATER SAFETY OF THE TOLL LANES IS NOT AS IMPORTANT TO ME
7. EASE OF DRIVING IN THE TOLL LANES IS NOT AS IMPORTANT TO ME
8. I NOW THINK THE TOLL LANES ARE NOT SAFER THAN THE FREE LANES
9. I NOW THINK THE TOLL LANES ARE NOT EASIER DRIVING THAN FREE LANES
10. PEOPLE I TRAVEL WITH NOW DON'T LIKE USING THE TOLL LANES
11. IT'S LESS IMPORTANT FOR ME TO BE ON TIME FOR WORK/HOME
12. I NOW TRAVEL AT A LESS CONGESTED TIME OF DAY
13. OTHER

SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER' (OTHER LINE

(Multiple Response)

SKIP AFTER Q134 GO 136

165. WHY HAS THE AMOUNT YOU USE THE ROUTE 91 TOLL LANES INCREASED SINCE TWO YEARS AGO ?

1. TRAFFIC IS MORE CONGESTED
2. I AM NOW SHARING THE TOLL
3. MY INCOME HAS CHANGED
4. I'VE GOTTEN USED TO THE IDEA OF PAYING A TOLL
5. GREATER SAFETY OF THE TOLL LANES IS MORE IMPORTANT TO ME NOW
6. EASE OF DRIVING IN THE TOLL LANES IS MORE IMPORTANT TO ME NOW
7. PEOPLE I TRAVEL WITH NOW PREFER THE TOLL LANES
8. IT'S MORE IMPORTANT FOR ME TO BE ON TIME FOR WORK/HOME

9. I NOW TRAVEL AT A MORE CONGESTED TIME OF DAY
 10. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
 ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

 136. NOW WHEN YOU DRIVE OR CARPOOL WESTBOUND INTO ORANGE COUNTY IN THE
 MORNING PEAK PERIODS, DO YOU USUALLY ARRIVE EARLIER, LATER, OR ABOUT
 THE SAME TIME AS YOU DID TWO YEARS AGO ?

1. EARLIER
2. LATER
3. SAME TIME
4. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q136 IF Q<24> NE "1" THEN GO 208
 SKIP AFTER Q136 IF Q<136> LE "2" THEN GO 210
 SKIP AFTER Q136 IF Q<136> GE "3" THEN GO 138

 137. WHY DO YOU NOW TRAVEL AT A DIFFERENT TIME ?

1. TRAFFIC IS WORSE
2. TO AVOID HIGHER TOLLS
3. HARDER/EASIER TO FIND A PLACE TO PARK
4. MY WORK OR PERSONAL SCHEDULE HAS CHANGED
5. THE PERSONS I TRAVEL WITH HAVE DIFFERENT SCHEDULE
6. THE NEED FOR ME TO BE AT WORK/HOME AT A PARTICULARE TIME IS LESS
7. I CARPOOL OR USE TRANSIT MORE OFTEN OR LESS OFTEN
8. THE ROUTE I TAKE IS DIFFERENT THAN TWO YEARS AGO
9. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
 ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

 138. DO YOU NOW HAVE A FASTRAK TRANSPONDER ?

1. YES
2. NO
3. DON'T KNOW/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q138 IF Q<138> EQ "3" THEN GO 148
 SKIP AFTER Q138 IF Q<138> EQ "1" THEN GO 140

 139. WHY DON'T YOU HAVE A FASTRAK TRANSPONDER ?

1. CONGESTION ISN'T BAD ENOUGH TO USE TOLL ROADS
2. TOLLS ARE TOO EXPENSIVE
3. COSTS OF HAVING TRANSPONDER IS TOO EXPENSIVE FOR OCCASIONAL USE
4. TOLL ROADS ARE NOT CONVENIENT FOR ME TO USE ON MY USUAL TRIPS
5. I HAVEN'T GOTTEN AROUND TO GETTING ONE YET
6. IT'S TOO MUCH TROUBLE
7. I DON'T HAVE A CREDIT CARD

8. I WOULDN'T USE IT ENOUGH TO BOTHER GETTING IT
9. I DON'T KNOW HOW TO GET ONE
10. I DON'T APPROVE OF TOLL ROADS
11. I HAD A TRANSPONDER BUT GOT RID OF IT
12. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

SKIP AFTER Q139 GO 216

140. FROM WHAT AGENCY DID YOU GET THE TRANSPONDER YOU USUALLY USE ?

1. 91 EXPRESS LANES (CPTC)
2. ORANGE COUNTY TOLL ROAD AGENCY (TCA)
3. I-15 LANES IN SAN DIEGO (SANDAG)
4. BAY AREA TOLL BRIDGES (CALTRANS CARQUINEZ BRIDGE)
5. OTHER (OTHER LINE = 355)

(PROMPT ONLY IF NO ANSWER)

145. DO YOU NOW OR HAVE YOU EVER BELONGED TO THE 91 EXPRESS CLUB FOR
FREQUENT USERS OF THE EXPRESS LANES ?

1. YES
2. NO, NEVER HAVE
3. NO, BUT ONCE DID
4. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP BEFORE Q145 IF Q<140> GE "2" THEN GO 146

146. WHO PAYS FOR YOUR TRANSPONDER ACCOUNT(S) ?

1. SELF
2. EMPLOYER
3. FAMILY MEMBER OR FRIEND
4. COMBINATION OF SELF AND EMPLOYER
5. COMBINATION OF SELF AND FAMILY OR FRIEND
6. COMBINATION OF SELF, EMPLOYER, AND FAMILY OR FRIEND
7. COMBINATION OF EMPLOYER AND FAMILY OR FRIEND
8. OTHER (OTHER LINE = 341)

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q146 IF Q<146> LE "3" THEN GO 148

SKIP AFTER Q146 IF Q<146> GE "7" THEN GO 148

147. WHAT PERCENTAGE OF YOUR TYPICAL DAILY PEAK PERIOD TRIPS ON TOLL
FACILITIES DO YOU PERSONALLY PAY FOR ?

*** SURVEYOR NOTE: CAPTURE ONLY A NUMBER, DON'T ACCEPT A RANGE ***

148. IN YOUR USUAL PEAK PERIOD TRAVEL, PLEASE TELL ME IF YOU USE ANY OF THE
FOLLOWING STRATEGIES TO AVOID TRAFFIC CONGESTION.

1. USE TOLL FACILITIES

2. LEAVE EARLY OR LATE TO AVOID PEAK PERIOD CONGESTION
3. JOIN CARPOOL TO USE CARPOOL LANES
4. USE SURFACE STREETS TO AVOID FREEWAY CONGESTION
5. DO NOTHING
6. DON'T KNOW/REFUSED
7. OTHER (OTHER LINE = 342)

(Multiple Response)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

149. BEFORE THE 91 EXPRESS LANES OPENED IN LATE 1995, WHICH OF THE FOLLOWING STRATEGIES DID YOU USE TO AVOID TRAFFIC CONGESTION ?

1. DID NOT COMMUTE ON THE 91 BEFORE EXPRESS LANES OPENED
2. LEAVE EARLY OR LATE TO AVOID PEAK PERIOD CONGESTION
3. JOIN CARPOOL TO USE CARPOOL LANES
4. USE SURFACE STREETS TO AVOID FREEWAY CONGESTION
5. DID NOTHING
6. DON'T KNOW/REFUSED
7. OTHER (OTHER LINE = 343)

(Multiple Response)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q149 GO 221

150. HOW DO YOU DECIDE WHETHER OR NOT YOU WILL USE THE 91 TOLL LANES FOR A PARTICULAR TRIP ?

1. I DO THE SAME THING EVERY DAY WITHOUT THINKING ABOUT IT
2. I OBSERVE TRAFFIC CONDITIONS AS I TRAVEL
3. I CHECK RADIO/TV/INTERNET TRAFFIC REPORTS
4. IT DEPENDS ON HOW MUCH CONGESTION THERE WAS IN RECENT DAYS
5. IT DEPENDS ON THE TIME OF DAY AND AMOUNT OF THE TOLL
6. IT DEPENDS ON WHETHER I'M TRAVELING ALONE OR WITH OTHERS
7. I NEVER USE THE TOLL FACILITIES
8. OTHER

SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCHES TO ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER' (OTHER LINE

(Multiple Response)

SKIP BEFORE Q150 IF Q<116> EQ "5" THEN GO 169
 SKIP BEFORE Q150 IF Q<206> EQ "5" THEN GO 169
 SKIP BEFORE Q150 IF Q<138> GE "2"
 AND Q<216> GE "2" THEN GO 169
 SKIP AFTER Q150 IF Q<150> EQ "7" THEN GO 169

151. ABOUT HOW MUCH TIME DO YOU THINK USING THE 91 TOLL LANES SAVES YOU ON A TYPICAL ONE-WAY TRIP INTO ORANGE COUNTY IN THE MORNING PEAK, COMPARED TO USING THE SR91 FREE LANES ?

*** SURVEYOR NOTE: CAPTURE IN MINUTES, JUST A NUMBER WITHOUT THE WORD MINUTES ***

152. ABOUT HOW MUCH TIME DO YOU THINK USING THE 91 TOLL LANES SAVES YOU ON A TYPICAL ONE-WAY TRIP FROM ORANGE COUNTY IN THE AFTERNOON PEAK,

COMPARED TO USING THE SR91 FREE LANES ?

*** SURVEYOR NOTE: CAPTURE IN MINUTES, JUST A NUMBER WITHOUT THE WORD MINUTES ***

153. BESIDES SAVING TIME, ARE THERE OTHER REASONS WHY YOU DECIDE TO USE THE 91 TOLL LANES ?

1. YES
2. NO
3. DON'T KNOW/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q153 IF Q<153> GE "2" THEN GO 165

154. WHAT ARE THE REASONS ?

1. MORE PREDICTABLE/SURPRISE DELAYS LESS LIKELY
2. EASIER AND MORE COMFORTABLE DRIVING
3. IT'S SAFER
4. ENJOY PASSING PEOPLE STUCK IN TRAFFIC
5. FEELING OF PRESTIGE
6. CAN EXCEED SPEED LIMIT WITH LITTLE RISK OF TICKET
7. OTHER

SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCHES TO ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER' (OTHER LINE

(Multiple Response)

SKIP AFTER Q154 GO 165

160. I WILL NOW ASK YOU SOME GENERAL QUESTIONS ABOUT YOUR OPINIONS ON THE 91 TOLL LANES . . . THE AMOUNT CHARGED ON THE TOLL LANES VARIES BASED ON THE AMOUNT OF CONGESTION THE USER AVOIDS. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

161. ADDITIONAL EXPRESS TOLL LANES FOR BYPASSING CONGESTION COULD BE CONSTRUCTED ALONG OTHER CONGESTED HIGHWAYS IN CALIFORNIA. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

162. PRIVATE COMPANIES SHOULD BE ALLOWED TO OPERATE TOLL ROADS AS A PROFIT MAKING BUSINESS. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

 163. SINGLE OCCUPANT VEHICLES COULD BE ALLOWED TO PAY ELECTRONIC TOLLS TO
 USE UNDER-USED CARPOOL LANES TO AVOID CONGESTION AS LONG AS THESE LANES
 DON'T BECOME CONGESTED. DO YOU THINK THIS IS . . . ?

1. A GOOD IDEA
2. A BAD IDEA
3. NO OPINION

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q163 IF Q<163> NE "2" THEN GO 169

 164. WHY DO YOU THINK THIS IS A BAD IDEA ?

1. ONLY BENEFITS THE RICH
2. NOT FAIR TO HAVE TOLLS ON ROADS WE'VE ALREADY PAID FOR
3. WILL DISCOURAGE CARPOOLING
4. WILL DISCOURAGE IMPROVEMENT/EXPANSION OF REGULAR HIGHWAYS
5. ROADS SHOULD BE FREE TO ALL
6. TOO COMPLICATED AND CONFUSING
7. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO
 ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'*** (OTHER LINE

(Multiple Response)

SKIP AFTER Q164 GO 169

 165. HOW DO YOU COMPARE THE SAFETY OF TRAVELING IN THE 91 TOLL LANES
 TO THE SAFETY OF USING THE REGULAR FREEWAY LANES - ARE THEY . . . ?

1. MUCH LESS SAFE
2. SOMEWHAT LESS SAFE
3. ABOUT THE SAME
4. SOMEWHAT SAFER
5. MUCH SAFER
6. DON'T KNOW / REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q165 IF Q<165> LE "2" THEN GO 167
 SKIP AFTER Q165 IF Q<165> EQ "3" THEN GO 169
 SKIP AFTER Q165 IF Q<165> EQ "6" THEN GO 169

 166. WHY DO YOU FEEL THE TOLL LANES ARE SAFER?

1. LESS TRAFFIC
2. LESS CONGESTION
3. NO TRUCKS OR LARGE VEHICLES
4. LESS AGGRESSIVE DRIVING (LANE CHANGING, CUTTING OFF)
5. PEOPLE WHO PAY TOLLS ARE BETTER DRIVERS
6. BETTER ENFORCEMENT
7. BETTER EMERGENCY RESPONSE
8. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCES TO

ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'***

(OTHER LINE

(Multiple Response)

SKIP AFTER Q166 GO 169

167. WHY DO YOU FEEL THE TOLL LANES ARE LESS SAFE?

1. HIGH SPEEDS
2. MORE AGGRESSIVE DRIVING
3. LESS TRAFFIC ENFORCEMENT
4. NO SHOULDERS
5. POORER DRIVERS USE TOLL LANES
6. POORER EMERGENCY RESPONSE
7. OTHER

***SURVEYOR NOTE: DO NOT PROMPT - SELECT BEST MATCH OR MATCHES TO

ANSWER GIVEN, IF NO GOOD MATCH, CODE AS 'OTHER'***

(OTHER LINE

(Multiple Response)

169. WHAT IS YOUR HOME ZIP CODE ?

170. HOW MANY DRIVERS LIVE IN YOUR HOUSEHOLD, INCLUDING YOURSELF ?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. 10 OR MORE

(DON'T READ PRE-CODED RESPONSES)

171. HOW MANY USABLE VEHICLES ARE AVAILABLE TO YOUR HOUSEHOLD ?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. OTHER (OTHER LINE = 347)

(DON'T READ PRE-CODED RESPONSES)

172. IF YOU ARE NOW EMPLOYED, WHAT KIND OF WORK DO YOU DO ?

1. SECRETARIAL/CLERICAL
2. PRODUCTION/CRAFTS/OFFICE WORK
3. SENIOR MANAGEMENT
4. MIDDLE MANAGEMENT
5. MAINTENANCE
6. SALES/SERVICE
7. PROFESSIONAL
8. CONSTRUCTION

- 9. MILITARY
- 10. OTHER
- 11. REFUSED/DON'T KNOW
- 12. RETIRED
- 13. STUDENT
- 14. UNEMPLOYED (OTHER LINE = 348)

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q172 IF Q<172> GE "11" THEN GO 177

173. DO YOU WORK FULL TIME OR PART TIME ?

- 1. FULL TIME
- 2. PART TIME
- 3. OTHER
- 4. DON'T KNOW/REFUSED (OTHER LINE = 349)

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q173 IF Q<173> LE "3" THEN GO 218

174. DOES YOUR (PRINCIPAL) PLACE OF EMPLOYMENT HAVE A FORMAL PROGRAM TO ENCOURAGE RIDESHARING OR TRANSIT USE ?

- 1. YES
- 2. NO
- 3. DON'T KNOW
- 4. REFUSED

(DON'T READ PRE-CODED RESPONSES)

175. DOES YOUR EMPLOYMENT PERMIT YOU TO WORK AT HOME ?

- 1. YES
- 2. NO
- 3. OTHER (OTHER LINE = 352)

(DON'T READ PRE-CODED RESPONSES)

177. HOW LONG HAVE YOU LIVED AT YOUR CURRENT ADDRESS ?

- 1. LESS THAN 1 YEAR
- 2. 1 - 5 YEARS
- 3. 5 - 10 YEARS
- 4. 10 - 20 YEARS
- 5. 20 YEARS OR MORE
- 6. REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q177 IF Q<177> GE "3" THEN GO 179

178. IN WHAT CITY DID YOU LIVE PREVIOUSLY ?

179. DOES YOUR HOUSEHOLD HAVE CHILDREN 18 YEARS OLD OR LESS ?

- 1. YES
- 2. NO
- 3. DON'T KNOW/REFUSED

4. OTHER (OTHER LINE = 350)

(DON'T READ PRE-CODED RESPONSES)

180. HOW MANY PEOPLE LIVE IN YOUR HOUSEHOLD (INCLUDING YOURSELF) ?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. 10 OR MORE
11. OTHER
12. REFUSED (OTHER LINE = 351)

(DON'T READ PRE-CODED RESPONSES)

181. PLEASE STOP ME WHEN I SAY THE CATEGORY THAT INCLUDES YOUR AGE . . . ?

1. IN YOUR 20'S
2. 30'S
3. 40'S
4. 50'S
5. OVER 60
6. REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

182. PLEASE STOP ME WHEN I SAY THE HIGHEST GRADE OF SCHOOL THAT YOU HAVE COMPLETED SO FAR.

1. HIGH SCHOOL OR LESS
2. SOME COLLEGE, TRADE OR VOCATIONAL SCHOOL
3. GRADUATED COLLEGE WITH BACHELOR'S DEGREE
4. GRADUATE WORK BEYOND BACHELOR'S DEGREE
5. DON'T KNOW/REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

183. PLEASE STOP ME WHEN I SAY THE CATEGORY THAT INCLUDES YOUR HOUSEHOLD'S TOTAL INCOME FOR 1998 BEFORE TAXES . . . ?

*** SURVEYOR NOTE: IF THEY DON'T KNOW HOUSEHOLD INCOME ASK FOR PERSONAL INCOME ***

1. LESS THAN \$10,000
2. \$10,000 - \$25,000
3. \$25,000 - \$40,000
4. \$40,000 - \$60,000
5. \$60,000 - \$100,000
6. \$100,000 AND ABOVE
7. REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

184. GENDER ?

*** SURVEYOR NOTE: COMPLETE BY OBSERVATION ***

1. MALE
2. FEMALE

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q184 GO 213

185. MAY WE CONTACT YOU FOR A FOLLOW-UP SURVEY ?

1. YES
2. NO
3. OTHER (OTHER LINE = 353)

(DON'T READ PRE-CODED RESPONSES)

186. MAY I HAVE YOUR FIRST AND LAST NAME PLEASE ?

SKIP BEFORE Q186 IF Q<185> EQ "2" THEN GO END
SKIP AFTER Q186 GO END

187. ABOUT WHAT TIME IN THE EVENING WERE ALL PASSENGERS TOGETHER
IN THE VEHICLE AND THE TRIP BEGAN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP AFTER Q187 GO 36

188. ABOUT WHAT TIME IN THE EVENING DID THIS TRIP BEGIN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM
AND PM IS VERY IMPORTANT ***

SKIP AFTER Q188 GO 42

189. ABOUT WHAT TIME IN THE EVENING DID THE FIRST PASSENGER GET TO
THEIR DESTINATION ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
IS VERY IMPORTANT ***

SKIP AFTER Q189 GO 47

190. APPROXIMATELY WHAT TIME IN THE EVENING DID YOUR TRIP END ?

SKIP AFTER Q190 GO 50

191. DURING THE PAST MONTH, DID YOU MAKE ANY AFTERNOON OR EVENING
TRIPS OUT OF ORANGE COUNTY BETWEEN 2PM AND 8PM, WHICH OCCURRED
ON FRIDAY ?

1. YES
2. YES, BUT MORE THAN A MONTH AGO
3. NO SUCH TRIPS ON A FRIDAY
4. TRAVELED OUT OF ORANGE COUNTY, BUT AT A DIFFERENT TIME
5. DON'T REMEMBER

6. REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q191 IF Q<191> EQ "6" THEN GO 111
 SKIP AFTER Q191 IF Q<191> EQ "5" THEN GO 196
 SKIP AFTER Q191 IF Q<191> EQ "4" THEN GO 196
 SKIP AFTER Q191 IF Q<191> EQ "3" THEN GO 196
 SKIP AFTER Q191 IF Q<191> EQ "2" THEN GO 196
 SKIP AFTER Q191 IF Q<191> EQ "1" THEN GO 192

192. ON THAT RECENT FRIDAY TRIP, DID YOU RIDE WITH THE SAME NUMBER OF PEOPLE AND USE THE SAME ROUTE INCLUDING PAYING OR NOT PAYING TOLLS, AS YOU DID ON THAT OTHER MIDWEEK TRIP YOU JUST TOLD ME ABOUT?

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q192 IF Q<192> EQ "3" THEN GO 111
 SKIP AFTER Q192 IF Q<192> EQ "2" THEN GO 60

193. ON THAT RECENT FRIDAY TRIP, DID YOU ARRIVE AT YOUR DESTINATION AT ABOUT THE SAME TIME IN THE MORNING AS YOU DID ON THAT OTHER MIDWEEK TRIP?

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q193 IF Q<24> NE "1" THEN GO 194
 SKIP AFTER Q193 IF Q<193> EQ "3" THEN GO 111
 SKIP AFTER Q193 IF Q<193> EQ "2" THEN GO 60
 SKIP AFTER Q193 IF Q<193> EQ "1" THEN GO 195

194. ON THAT RECENT FRIDAY TRIP, DID YOU START YOUR TRIP AT ABOUT THE SAME TIME IN THE EVENING AS YOU DID ON THAT OTHER MIDWEEK TRIP?

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q194 IF Q<194> EQ "3" THEN GO 111
 SKIP AFTER Q194 IF Q<194> EQ "2" THEN GO 60
 SKIP AFTER Q194 IF Q<194> EQ "1" THEN GO 196

195. THINKING BACK TO THE WEEK WHEN YOU MADE THAT MIDWEEK TRIP YOU JUST TOLD ME ABOUT, WAS THERE ANY DAY THAT WEEK WHEN YOUR MORNING TRIP INTO ORANGE COUNTY BETWEEN 4AM AND 10AM WAS MADE IN A DIFFERENT WAY ? FOR EXAMPLE, YOU RODE WITH A DIFFERENT NUMBER OF PEOPLE, TOOK A DIFFERENT ROUTE INCLUDING PAYING OR NOT PAYING TOLLS, OR ARRIVED AT A DIFFERENT TIME?

1. YES

2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q195 IF Q<25> NE "1"
 AND Q<26> NE "1" THEN GO 111
 SKIP BEFORE Q195 IF Q<24> NE "1" THEN GO 196
 SKIP AFTER Q195 IF Q<195> GE "2" THEN GO 111
 SKIP AFTER Q195 IF Q<195> EQ "1" THEN GO 197

 196. THINKING BACK TO THE WEEK WHEN YOU MADE THAT MIDWEEK TRIP YOU JUST
 TOLD ME ABOUT, WAS THERE ANY DAY THAT WEEK WHEN YOUR EVENING TRIP
 OUT OF ORANGE COUNTY BETWEEN 2PM AND 8PM WAS MADE IN A DIFFERENT
 WAY? FOR EXAMPLE, YOU RODE WITH A DIFFERENT NUMBER OF PEOPLE, TOOK
 A DIFFERENT ROUTE INCLUDING PAYING OR NOT PAYING TOLLS, OR BEGAN
 YOUR TRIP AT A DIFFERENT TIME?

1. YES
2. NO
3. DON'T REMEMBER/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP BEFORE Q196 IF Q<25> NE "1"
 AND Q<26> NE "1" THEN GO 111
 SKIP AFTER Q196 IF Q<196> GE "2" THEN GO 111

 197. WHAT DAY OF THE WEEK WAS IT WHEN SOMETHING ABOUT YOUR TRIP WAS
 DIFFERENT?

1. MONDAY
2. TUESDAY
3. WEDNESDAY
4. THURSDAY
5. FRIDAY
6. SATURDAY OR SUNDAY

** SURVEYOR NOTE: IF MORE THAN ONE DAY, ASK RESPONDENT TO PICK **
 ** ONE DAY, PREFERABLY THE ONE WHICH WAS MORE DIFFERENT **

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q197 IF Q<197> LE "5" THEN GO 60
 SKIP AFTER Q197 IF Q<197> EQ "6" THEN GO 111

 198. ABOUT WHAT TIME IN THE EVENING WERE ALL PASSENGERS TOGETHER
 IN THE VEHICLE AND THE TRIP BEGAN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM
 AND PM IS VERY IMPORTANT ***

SKIP AFTER Q198 GO 67

 199. ABOUT WHAT TIME IN THE EVENING DID THIS TRIP BEGIN ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM
 AND PM IS VERY IMPORTANT ***

SKIP AFTER Q199 GO 73

YEARS AGO ?

1. TRAFFIC IS WORSE
2. THE TOLLS ARE HIGHER
3. PARKING IS MORE/LESS DIFFICULT
4. I NEED MY CAR MORE/LESS OFTEN FOR WORK/PERSONAL REASONS
5. I WORK AT HOME MORE OFTEN AND CANNOT CARPOOL
6. PEOPLE I TRAVEL WITH NEED THEIR CAR MORE/LESS OFTEN
7. I MAKE MORE TRIPS AT OFF-PEAK TIMES AND CAN'T CARPOOL
8. THE NATURE OF MY WORK HAS CHANGED
9. OTHER (OTHER LINE = 336)

(Multiple Response)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q205 GO 116

206. IN THE EVENING PEAK PERIOD TRAVELING EASTBOUND OUT OF ORANGE COUNTY, MONDAY THROUGH FRIDAY, IS THE AMOUNT YOU NOW USE THE ROUTE 91 TOLL LANES GREATER OR LESS THAN TWO YEARS AGO ?

1. GREATER
2. LESS
3. NO CHANGE
4. DON'T REMEMBER
5. I NEVER USE THE 91 TOLL LANES
6. REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q206 IF Q<206> EQ "1" THEN GO 135

SKIP AFTER Q206 IF Q<206> EQ "2" THEN GO 134

SKIP AFTER Q206 IF Q<206> EQ "3" THEN GO 136

SKIP AFTER Q206 IF Q<206> EQ "4" THEN GO 136

SKIP AFTER Q206 IF Q<206> EQ "5" THEN GO 136

SKIP AFTER Q206 IF Q<206> EQ "6" THEN GO 138

208. NOW WHEN YOU DRIVE OR CARPOOL EASTBOUND OUT OF ORANGE COUNTY IN THE EVENING PEAK PERIODS, DO YOU USUALLY DEPART EARLIER, LATER, OR ABOUT THE SAME TIME AS YOU DID TWO YEARS AGO ?

1. EARLIER
2. LATER
3. SAME TIME
4. DON'T KNOW/REFUSED

(PROMPT ONLY IF NO ANSWER)

SKIP AFTER Q208 IF Q<208> GE "3" THEN GO 138

209. HOW MANY MINUTES EARLIER OR LATER DO YOU NOW USUALLY DEPART ?

SKIP AFTER Q209 GO 137

210. HOW MANY MINUTES EARLIER OR LATER DO YOU NOW USUALLY ARRIVE ?

SKIP AFTER Q210 GO 137

211. ENTER 'A' BLOCK OR 'B' BLOCK.

 200. ABOUT WHAT TIME IN THE EVENING DID THE FIRST PASSENGER GET TO THEIR
 DESTINATION ?

*** SURVEYOR NOTE: USE THIS FORMAT 8:30 AM INCLUDING AM AND PM
 IS VERY IMPORTANT ***

SKIP AFTER Q200 GO 78

 201. APPROXIMATELY WHAT TIME IN THE EVENING DID YOUR TRIP END ?

SKIP AFTER Q201 GO 81

 202. THINK BACK TO TWO YEARS AGO THIS MONTH AND ABOUT THE NUMBER OF
 EASTBOUND TRIPS YOU MADE OUT OF ORANGE COUNTY MONDAY THROUGH FRIDAY
 BETWEEN 2PM AND 8PM. TWO YEARS AGO WERE YOU USUALLY MAKING:

1. ABOUT THE SAME NUMBER OF TRIPS
2. MORE PM EASTBOUND TRIPS THAN TODAY
3. FEWER PM EASTBOUND TRIPS THAN TODAY
4. DON'T KNOW / DON'T REMEMBER / REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q202 IF Q<202> EQ "3" THEN GO 114
 SKIP AFTER Q202 IF Q<202> EQ "1" THEN GO 115
 SKIP AFTER Q202 IF Q<202> EQ "4" THEN GO 115
 SKIP AFTER Q202 GO 113

 203. COMPARING YOUR PRESENT TYPICAL EVENING EASTBOUND PEAK PERIOD
 TRAVEL MONDAY THROUGH FRIDAY TO TWO YEARS AGO, HAS THE OVERALL
 AMOUNT YOU DRIVE ALONE, CARPOOL OR TAKE TRANSIT CHANGED ?

1. YES
2. NO
3. DON'T REMEMBER
4. REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q203 IF Q<203> EQ "3" THEN GO 116
 SKIP AFTER Q203 IF Q<203> EQ "4" THEN GO 138
 SKIP AFTER Q203 IF Q<203> EQ "2" THEN GO 116

 204. TYPICALLY, DURING THIS TIME PERIOD DO YOU NOW CARPOOL OR
 VANPOOL . . . ?

1. MUCH MORE (3+ MORE DAYS/WEEK)
2. A LITTLE MORE (ABOUT 1-2 MORE DAYS/WEEK)
3. MUCH LESS
4. A LITTLE LESS
5. ABOUT THE SAME
6. DON'T KNOW/REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q204 IF Q<204> EQ "5" THEN GO 215
 SKIP AFTER Q204 IF Q<204> EQ "6" THEN GO 116

 205. WHY HAS YOUR USE OF CARPOOLS OR TRANSIT CHANGED COMPARED TO TWO

1. A-BLOCK
2. B-BLOCK

Rotates pre-coded responses

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q211 IF Q<211> EQ "1" THEN GO 150
 SKIP AFTER Q211 IF Q<211> EQ "2" THEN GO 160

 212. CAPTURE ANY SORT OF ACCENT.

*** SURVEYOR NOTE: COMPLETE BY OBSERVATION ***

1. NO FOREIGN ACCENT APPARENT
2. APPARENT SPANISH ACCENT
3. APPARENT ASIAN ACCENT
4. OTHER ACCENT

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q212 GO 22

 213. CAPTURE ANY SORT OF ACCENT.

*** SURVEYOR NOTE: COMPLETE BY OBSERVATION ***

1. NO FOREIGN ACCENT APPARENT
2. APPARENT SPANISH ACCENT
3. APPARENT ASIAN ACCENT
4. OTHER ACCENT

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q213 GO 185

 215. TYPICALLY, DURING THIS TIME PERIOD, DO YOU NOW TAKE PUBLIC
 TRANSIT . . . ?

1. MUCH MORE (3+ MORE DAYS/WEEK)
2. A LITTLE MORE (ABOUT 1-2 DAYS/WEEK)
3. MUCH LESS
4. A LITTLE LESS
5. ABOUT THE SAME
6. DON'T KNOW/REFUSED

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q215 IF Q<215> GE "5" THEN GO 116
 SKIP AFTER Q215 GO 205

 216. DO YOU EVER USE THE ROUTE 91 TOLL LANES DURING PEAK PERIODS
 TRAVELING WITH SOMEONE WHO HAS A TRANSPONDER ?

1. YES
2. NO
3. DON'T KNOW/REFUSED

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q222 GO 38

223. WHAT IS YOUR PRIMARY REASON FOR BEING IN THIS CARPOOL/VANPOOL ?

1. TO GIVE OR SHARE A RIDE WITH ANOTHER MEMBER OF MY HOUSEHOLD
2. TO SAVE TIME BY USING HOV LANES
3. TO SHARE THE COST OF TRAVEL SUCH AS GAS, OIL, ETC.
4. TO SHARE THE DRIVING TASK
5. BECAUSE I CAN'T USE MY OWN CAR
6. TO HELP THE ENVIRONMENT
7. TO GET A BENEFIT FROM EMPLOYER SUCH AS PREFERENTIAL PARKING, ETC
8. FOR THE COMPANIONSHIP
9. OTHER
10. DON'T KNOW/REFUSED (OTHER LINE = 360)

(READ PRE-CODED RESPONSES-EXCEPT FOR 'DON'T KNOW', 'REFUSED', ETC)

SKIP AFTER Q223 GO 69

224. IN WHAT CITY DO YOU LIVE IN ?

1. CORONA
2. RIVERSIDE
3. NORCO
4. MORENO VALLEY
5. LAKE ELSINORE
6. WILDOMAR
7. PERRIS
8. SUNCITY
9. TEMECULA
10. CHINO
11. MURRIETTA
12. MENIFEE

(DON'T READ PRE-CODED RESPONSES)

SKIP AFTER Q224 IF Q<224> EQ "1" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "3" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "5" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "4" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "2" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "7" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "9" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "11" THEN GO END
 SKIP AFTER Q224 IF Q<224> EQ "12" THEN GO END
 SKIP AFTER Q224 GO 3

VITA

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Honors and Awards

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Publications and Presentations

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